B Pasteurization Dairy

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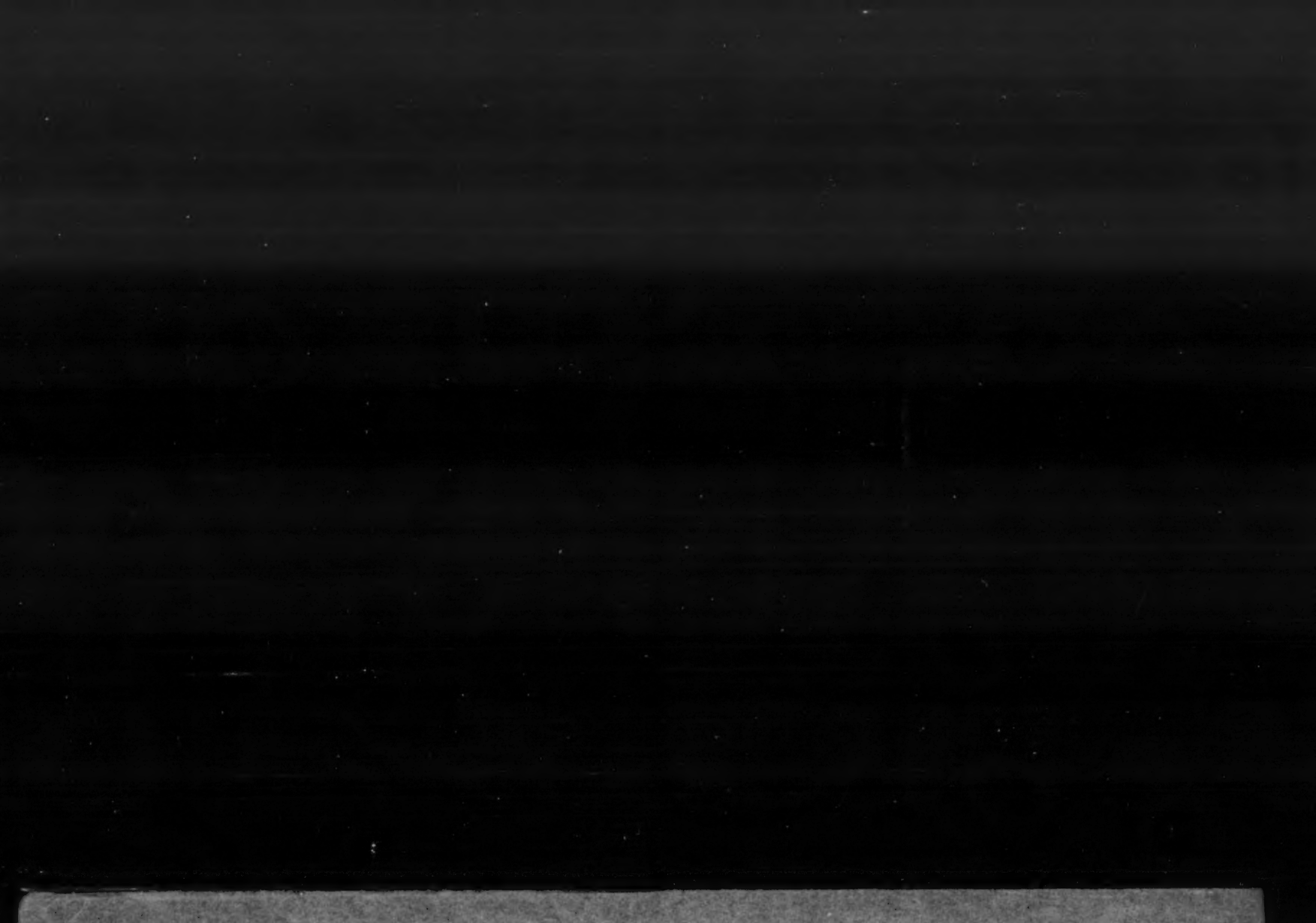

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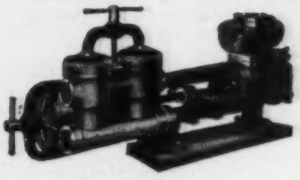

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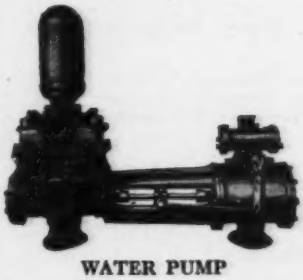

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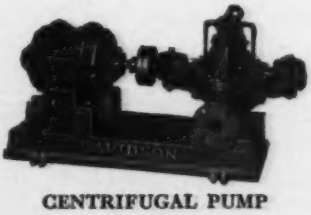

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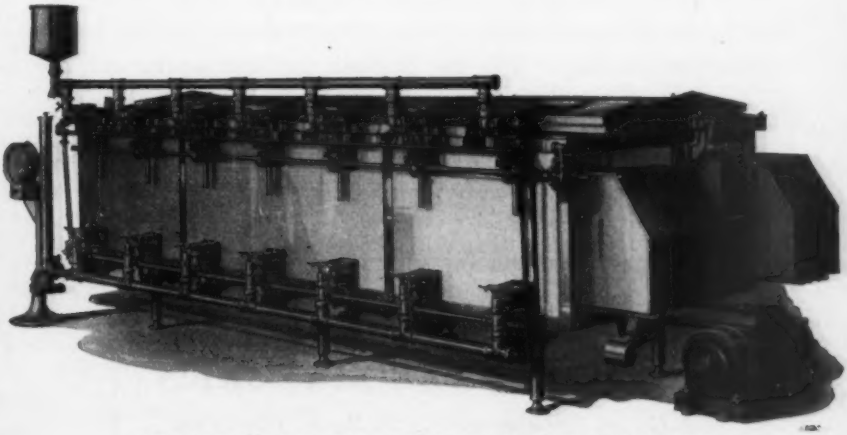

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SOME FACTORS CONCERNING THE "PARTIAL NEUTRALIZATION" OF CREAM FOR BUTTERMAKING*

B. A. STIRITZ AND H. A. REUHE

Department of Dairy Husbandry, University of Illinois, Urbana, Illinois

Much of the butter made in creameries today is manufactured from cream in which the acid has been reduced by the addition of some weak alkali, as lime, soda ash or sodium bicarbonate. The purpose of neutralizing is to get the cream in shape for proper pasteurization. There is no doubt that the flavor is improved as well as the keeping quality where neutralization and pasteurization are used. Uniform butter can be made from day to day by controlling the acidity through neutralization and ripening of the cream. On the other hand, unless care is exercised, the use of a neutralizer may impair the quality of the butter by imparting a limy flavor, due to lime particles, or a soapy flavor because of the saponification of some of the fats.

It is not known just when the first neutralizer was used in the buttermaking process, but Flint, in 1858, stated that the use of soda and water will improve the quality of the butter (1). In 1901–1902 extensive experiments were carried out by Prof. G. L. McKay in which he used various alkalis for reducing the acidity of the cream (2) (3). As early as 1905, some creameries were using lime in buttermaking on a commercial scale (2). Since that time, the practice has spread rapidly. It is used practically in every creamery of the centralizer class and many of the smaller factories. From time to time, various alkalis were used for the reduction of the acid in cream (2), (4), but the general practice today is to use lime, soda ash or sodium bicarbonate or a combination of two of these.

In the use of the neutralizer, most plants use a 15 per cent mixture of lime and water (3) (4) or a 8 to 10 per cent solution of soda ash or sodium bicarbonate. To secure the best results in butter-

* Received for publication May 9, 1925.

making, the cream must be pasteurized after it is neutralized, except when sweet cream is churned. In the latter, pasteurization is employed but the cream is not neutralized as the acid content is low.

The advantages gained from neutralizing cream are well known. It avoids excess fat losses and curd particles in the butter which results from the pasteurization of sour cream. To a certain extent, it prevents flavors which result from churning sour cream. Along with efficient pasteurization, it improves the keeping qualities of butter made from a high acid cream.

The object of these experiments was not to compare neutralized cream with unneutralized cream, but to compare the effect of the use of various neutralizers on the quality of the finished butter (made from the same cream), the keeping quality of the butter, and on the fat losses in the buttermilk.

Before the main experiments were carried out, many preliminary tests were run to determine the factors most favorable to the correct neutralization of the cream, such as the strength of the neutralizer to use; the time required for the neutralizer to react with the acid after it is added to the cream; and the amount of the reduction in acidity which takes place during the pasteurization process.

EXPERIMENTAL WORK

In every case, the temperature of the cream, when neutralized, was between 90° and 100°F. This temperature was used, as the authors found (some unpublished results obtained during the summer of 1922 with lime) that lower temperatures tend to produce a butter with a neutralizer flavor; while 115°F. tends to give a scorched flavor to the butter. The temperature of 90° to 100°F. gave the best flavored butter.

In each pasteurization, the cream was heated to 160°F., held fifteen minutes, and then cooled as rapidly as possible.

Strength of the neutralizer

The neutralizers used in the preliminary work were slaked lime, Lehigh Lime, soda ash and sodium bicarbonate. The Lehigh

Lime was used because it is a true representative example of relatively pure calcium lime as sold to creameries for neutralizing purposes. The strengths of the Lehigh Lime used were 10 15, and 25 per cent, those of the soda ash and sodium bicarbonate were 5, 10 and 20 per cent.

The lime mixtures were prepared as follows: for the 10 per cent Lehigh Lime mixture, 100 grams of lime were weighed and this amount was added to 900 cc. of hot water. For the 15 and 25 per cent mixtures, the same procedure was followed except that 150 and 250 grams were put in 850 and 750 cc. of hot water respectively.

In the case of the 10 per cent slaked lime mixture, 100 grams of rock lime were weighed, and to this, 500 cc. of boiling water were added. The lime was allowed to slake and then it was diluted with 400 cc. of water. In preparing the 15 and 25 per cent mixtures, the same procedure was followed. One hundred and fifty and 250 grams of rock lime were placed in separate jars. To the former, approximately 400 cc. of boiling water were added; to the latter, 300 cc. of boiling water. After the lime was slaked, each mixture was diluted with 450 cc. of water.

In using lime, an attempt was made to secure as fine a suspension of the lime particles as possible by shaking and by using hot water, so that the danger of large particles of lime showing up in the butter was minimized.

The soda ash and the sodium bicarbonate are both fairly soluble in water. In preparing the 5, 10, and 20 per cent solutions of these neutralizers, 50, 100 and 200 grams of each were weighed and placed in separate jars. To these, 950, 900 and 800 cc. of warm water were added in the order named.

Two sets of churnings were made with each strength neutralizer and the same cream was used to complete each set with the various strength neutralizers. The cream was divided into four equal lots of 2000 grams each. The acidity of each lot was determined as follows: A 17.6 cc. pipette was used to transfer 17.5 cc. of the cream to a white cup. The pipette was then rinsed with distilled water and the rinsings placed in the cup with the cream. Three to five drops of phenolphthalein solution were

used as an indicator. The acid in the cream was then titrated with a tenth normal sodium hydroxide solution from a 50 cc. burette until a faint pink color appeared and remained for at least thirty seconds. The amount of the alkali used was then read from the burette and the total acidity in the cream was calculated as lactic acid.

One lot was neutralized with the stronger neutralizer; the second with the medium strength; the third with the weaker solution; and the fourth was not neutralized but was used as a check churning. In each case, except the last, the acidity was reduced to approximately the same point or near 0.2 per cent acid. In this series of experiments, the cream was not pasteurized. It was held in individual jars in a room at 35°F. for fifteen to eighteen hours. The cream was then warmed to 54°F., and churned in a glass dasher churn until the butter granules were about the size of wheat grains. The time of churning was noted in each case. The buttermilk was drained through two thicknesses of cheese cloth to prevent the larger butter granules from getting into the buttermilk. A sample was saved in each case. Each lot of butter was then washed with ½ gallon of water at 58°F. No salt was added. The butter was then worked with wooden ladles and placed in storage at 35°F. The next day these lots of butter were scored mainly for quality because the main object was to see the effect of the various strength neutralizers on the flavor of the butter.

The buttermilk was tested by the normal butyl alcohol method. Tracy and Overman (5) found this test checked very close with the Roese-Gottlieb method of the determination of fat. This test is as follows: A double neck skimmilk bottle, as used in the Babcock Test, was used. Two cubic centimeters of normal butyl alcohol were pipetted into each bottle. Eight and eight-tenths cubic centimeters of a well mixed sample of buttermilk were placed in each bottle from a 8.8 cc. pipette. Nine cubic centimeters of sulphuric acid (specific gravity 1.82 to 1.83) were added and mixed with the milk by rotating the bottle. When the color of the mixture had turned to a dark brown, the bottle was centrifuged for five minutes. Then warm distilled water was

added up to the base of the neck of the bottle; the bottle was centrifuged two minutes; warm water was added until the fat column rose in the capillary neck of the bottle; the bottle was centrifuged one minute; and then the fat column was read with the aid of a pair of dividers. The reading which was obtained was multiplied by two as a 9 gram sample of buttermilk was used in an 18 gram test bottle.

The results which were obtained are found in table 1.

Time for the neutralizer to react with the acid in the cream

To determine the time which is necessary for the complete reaction of the neutralizer upon the acid in the cream, the following experiments were carried out. The neutralizers used were: 5 per cent soda ash; 5 per cent sodium bicarbonate; 10 per cent Lehigh Lime; 10 per cent slaked lime; 10 per cent Peerless Lime; 10 per cent Milk of Magnesia (Allwood); 10 per cent Kelly Island Lime, a mixture made by mixing equal parts of a 5 per cent soda ash solution and a 10 per cent Lehigh Lime mixture before adding it to the cream; and a mixture of equal parts of a 5 per cent sodium bicarbonate solution and a 10 per cent Lehigh Lime mixture before adding it to the cream. The method used in preparing the slaked lime, Lehigh Lime, soda ash and sodium bicarbonate has been outlined. The other limes were prepared in the same way as was the Lehigh Lime.

The following chemical analyses of the various neutralizers were either furnished by the manufacturers or made by the Chemistry Department, University of Illinois.

The soda ash was "C.P." sodium carbonate crystals and the sodium bicarbonate was "C.P." crystals as manufactured and sold by Powers-Weightman-Rosengarten Company of Philadelphia.

The slaked lime was prepared from pure calcium oxide with the following maximum limit of impurities:

	per cent
Volatile substances	7.500
Chlorides	0.005
Silica	0.100
Sulphates	0.200
Alumina	0.350

The Lehigh Lime contains:

	per cent
Calcium hydrate	96.90
As listed:	
Calcium oxide	72.93
Loss (moisture)	23.97
Iron and alumina	0.48
Silica	1.16
Magnesium oxide	1.25

The Peerless Neutralizer Lime contains:

	per cent
Calcium hydroxide	97.35
Calcium carbonate	1.42
Iron and alumina	0.37
Silica	0.52
Magnesium oxide	0.25
Sulphates	trace

The Kelly Island Lime contains:

	per cent
Calcium oxide	49.70
Magnesium oxide	32.60
Silica	0.30
Iron and alumina	0.20
Loss on ignition	17.00

The Milk of Magnesia (Allwood Laboratories) Lime contains:

	per cent
Insoluble sulphur dioxide	0.14
Iron oxide	0.38
Aluminum oxide	0.04
Calcium oxide	62.94
Magnesium oxide	27.24
Loss on ignition	8.64

Six deteminations were made with each neutralizer. One thousand grams of cream were placed in the inner vessel of a double boiler. The outer vessel was filled with water and heated over a gas flame. When the temperature of the cream reached 100°F. the inner vessel containing the cream was removed and placed in a water bath which had a temperature of 100°F. The acidity was determined with tenth normal sodium hydroxide

and calculated as lactic acid. The neutralizer was added to the cream during the thorough agitation with a large spoon. The acidity was determined after one minute, two minutes, four minutes, five minutes, ten minutes, fifteen minutes, twenty minutes and twenty-five minutes. The results which were obtained are found in table 2.

Reduction in acidity due to the pasteurization process

Every creameryman has experienced some reduction in the acidity of cream during the pasteurization process. Experiments were made to determine the reduction of acidity during pasteurization. All neutralizers used in the preceding set of experiments were used.

Each experiment was carried on as follows: One thousand grams of cream were placed in the inner vessel of a double boiler and neutralized at 100°F. to approximately 0.2 per cent acid. The cream was held at this temperature long enough for the complete reaction of the alkali and acid. Fifteen minutes after the neutralizer was added, the amount of acidity was determined with tenth normal sodium hydroxide, the acidity being calculated as lactic acid. The cream was then heated to 160°F. in the double boiler, held at this temperature for fifteen minutes and then cooled with water to approximately 100°F. The acidity was again determined and the difference in acidities, before and after pasteurization, was taken as the reduction due to pasteurization. The results are shown in table 3.

Effect of various neutralizers on the quality of the butter, storage properties and fat losses in the buttermilk

After the preliminary tests to determine the best strength of each neutralizer to use and also the amount of the reduction in acidity to expect during the pasteurization process, larger churnings were made to determine the effects of the various neutralizers on the quality of the butter and on the fat losses in the buttermilk. The neutralizers which were used were 5 per cent solutions of soda ash and sodium bicarbonate and 10 per cent mixtures of the following limes: slaked lime; Lehigh Lime; Milk of Magnesia (Allwood); Kelly Island Lime and Peerless Lime. These were used alone and also in various combinations.

Each of these churnings was made with 50 pounds of cream. The churns used were Victor Juniors, number one, with two roll internal workers, each having a capacity of 30 pounds of finished butter. Both churns were operated from the same line shaft and had the same speed.

The cream used was of average quality as received at a large commercial plant. Sufficient cream was taken for all churnings in each series. The cream was placed in a 30 gallon, double jacketed starter can and the temperature was raised to 100°F. A sample was taken and tested for butterfat by the ordinary Babcock test for cream. The acidity was determined as lactic acid with a tenth normal alkali solution.

Lots of cream weighing exactly 50 pounds were placed in 10 gallon milk cans. These cans were placed in a large water tank and surrounded by water having a temperature of 100°F. Then each lot was neutralized with a specific neutralizer to approximately 0.20 per cent acid. The cream was agitated thoroughly with a stirring rod as the neutralizer was added. Fifteen minutes after the addition of the neutralizer, the acidity was again determined. If it was not at approximately 0.2 per cent acid, a sufficient amount of the neutralizer was added to lower the acidity to the desired amount. The water surrounding the 10 gallon milk cans was then heated to about 180°F. by using live steam. The cream in each can was stirred occasionally with a metal stirring rod and the temperature was watched carefully. When the temperature of the cream reached 160°F., the water which surrounded the cans was cooled to the same degree. The cream was allowed to remain at this temperature for fifteen minutes. The hot water was drawn off and the cans surrounded with water at approximately 68°F. (temperature of the tap water in the creamery). The cream was allowed to remain in this water with occasional stirring until the temperature was lowered to near 75°F. No starter was used. Each lot of cream was then placed in a cold room (35°F.) and held for twelve to fifteen hours. After this period of holding, two cans were removed at a time placed in warm water, and the cream heated to 54°F., the churning temperature in each case. It was held at this temperature for

thirty minutes previous to churning. Each lot was tested for acidity and poured through a strainer into a Victor Junior, number one churn. No color was added. The cream was churned until the butter granules were the size of wheat grains. The exact time of churning was taken. The butttemilk was drained off and a sample taken for a fat test. The butter was washed by adding 50 pounds of water and revolving the churn in high gear for ten revolutions. In each case, the temperature of the wash water was the same as that of the buttermilk when it was drawn from the churn. The wash water was drawn off and the butter was salted at the rate of two-thirds ounce of salt to each pound of butterfat in the cream as calculated from the weight and test of the cream. The dry salt method was used. The butter was worked by revolving the churn in low gear with the workers in operation for twenty-four revolutions. Four 1 pound samples were taken from each churning and placed in the storage room at a temperature of 35°F. One sample was scored the next day and the other three, at intervals of thirty days (thirty, sixty and ninety days).

The sample of buttermilk from each churning was tested by the normal butyl alcohol method, as previously outlined.

Each lot of cream in a series of churnings was handled exactly the same in every respect. They were weighed, neutralized, pasteurized, cooled and held as a unit. Two lots were warmed to the churning temperature and churned at the same time in similar churns which were driven by the same line shaft and motor.

The cream was stirred thoroughly as it was neutralized, heated and cooled but care was exercised not to cause mealiness in the finished butter by too violent agitation. In each case, the neutralizer solution was shaken well before it was used. When lime solutions were used, the mixture was allowed to stand for a few seconds after being mixed to allow any large particles to settle to the bottom before taking any out for use. This would tend to eliminate a limy flavor in the butter due to the presence of lime particles.

The results which were obtained with the various churnings are found in tables 1 to 6.

DISCUSSION OF RESULTS

Various strengths of neutralizers and the quality of the butter

The effect of the various strengths of neutralizers on the quality of the finished butter is found in table 1. The general practice in creameries is to use an 8 or 10 per cent solution of soda ash or sodium bicarbonate and a 15 per cent suspension of lime in water. The latter is made usually by adding 85 pounds of hot or boiling water to 15 pounds of the lime or in this proportion if a larger amount is desired. The results show clearly that the better quality of butter results from using the weaker solutions. In each case, the cream which was neutralized with the weaker solutions gave a bettter quality of butter than the check or unneutralized churning. This cannot be said of the churnings which were neutralized with the stronger solutions because of the decided neutralizer or soapy flavor which resulted in the finished butter.

In considering the scores of the butter from each churning, the 5 per cent solution of soda ash or sodium bicarbonate resulted in a finished quality of 1.5 to 4 per cent better than did the 10 per cent solution, while it was 8 to 9 per cent better than the 20 per cent solution. Practically the same thing can be said when using lime. The 10 per cent suspension gave a finished quality of 1 to 2 per cent better than the 15 per cent mixture and 2 to 9 per cent better than the 25 per cent mixture.

Various strengths of neutralizers and the loss of fat in the buttermilk

Table 1 shows the effect of the various strengths of neutralizers on the loss of the butterfat in the buttermilk. The weaker strength of each neutralizer resulted in the lower fat losses. This is true in each case except the sodium bicarbonate. This exception gave practically no difference between the 5 and 10 per cent solutions. The stronger solutions resulted in the per cent of butterfat in the buttermilk increasing from 0.60 and 0.79 to 0.81 and 0.94 per cent. The soluble neutralizers do not act the same as do the limes. The addition of the weaker lime mixtures resulted in a lower fat loss as compared with the check or unneu-

tralized churning; while the soluble neutralizers resulted in a higher far loss (even with the weaker solutions) than did the check churning.

The results given in table 1 show that the use of the weaker neutralizers had two advantages; a better quality butter, and a more complete churning. Both of these factors are vital in the operation of a creamery.

TABLE 1

Effect of the various strength neutralizers on the quality of the butter and on the butterfat lost in the buttermilk

NEUTRALIZER USED	STRENGTH	RELATIVE SCORE*	PER CENT OF FAT IN BUTTERMILK
	per cent		*per cent*
Soda ash	Check	84	0.62
	5	100	0.65
	10	96	0.74
	20	92	0.87
Sodium bicarbonate	Check	90	0.58
	5	100	0.79
	10	99	0.77
	20	91	0.94
Lehigh lime	Check	95	0.82
	10	100	0.60
	15	98	0.73
	25	91	0.81
Slaked lime	Check	93	0.74
	10	100	0.67
	15	99	0.74
	25	98	0.90

* The relative score is given on a percentage basis. The best butter was given a factor of 100; the others as percentages of the best. Each figure represents the average of two or three churnings.

The reaction of the neutralizer and the acid which is present in the cream

Table 2 shows the rapidity with which the various neutralizers react with the acid in the cream and the time which must lapse to insure a complete reaction. To discuss properly the data and

that which follows, it is well to group the various neutralizers into different classes, since some of them act practically the same. As the soda ash and the sodium bicarbonate are soluble in water, they will be called the soluble neutralizers. The Lehigh Lime, the Peerless Lime and the slaked lime are composed mainly of calcium hydroxide and these will be known as the calcium limes. The Milk of Magnesia (Allwood) Lime and the Kelly Island Lime

TABLE 2*

The rapidity with which the various neutralizers react with the cream prior to pasteurization

NEUTRALIZER USED	PER CENT ACIDITY AT VARIOUS TIMES									TIME FOR COMPLETE REDUCTION TO TAKE PLACE
	Before Adding	1 minute	2 minutes	4 minutes	5 minutes	10 minutes	15 minutes	20 minutes	25 minutes	
	per cent	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*minutes*
Lehigh Lime	0.62	0.38	0.35	0.31	0.31	0.31	0.31	0.31	0.31	4
Slaked lime	0.63	0.30	0.24	0.20	0.18	0.18	0.18	0.18	0.18	5
Peerless Lime	0.63	0.36	0.30	0.20	0.18	0.18	0.18	0.18	0.18	5
Allwood Lime	0.60	0.33	0.28	0.22	0.19	0.18	0.15	0.15	0.15	15
Kelly Island Lime	0.58	0.35	0.26	0.22	0.19	0.17	0.17	0.17	0.17	10
Soda ash	0.71	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	1
Sodium bicarbonate	0.64	0.32	0.28	0.28	0.28	0.28	0.28	0.28	0.28	2
50–50 mixture Lehigh Lime and soda ash	0.62	0.30	0.25	0.22	0.22	0.22	0.22	0.22	0.22	4
50–50 mixture Lehigh Lime and sodium bicarbonate	0.64	0.32	0.29	0.27	0.27	0.27	0.27	0.27	0.27	4
Average for all										4.5

* The table gives the averages of six determinations for each neutralizer.

contains much more magnesium hydrate than the calcium limes so they will be known as the magnesium limes. The other group will be known as the mixed neutralizers because they are composed of equal parts of a10 per cent solution of Lehigh Lime and a 5 per cent solution of either soda ash or sodium bicarbonate.

The soluble neutralizers react almost immediately with the acid in the cream. If the neutralizer and the cream are agitated well at the time of mixing, it is safe to check the acidity of the cream in

four minutes (this allows a safety factor of two minutes) and thus be certain that there will be no further reduction in the acidity prior to pasteurization.

All the lime neutralizers react slower in reducing the acidity because they are not completely soluble. No two classes of lime neutralizers react exactly alike. The calcium limes react completely in four to five minutes. If the cream is agitated thoroughly as the calcium limes are added, one can be sure that the reaction is complete in seven minutes (which includes two minutes as a safety factor) and there will be no further decrease in the acidity of the cream before pasteurization.

The magnesium limes react slower than do the calcium limes. This can be explained by the fact that magnesium hydroxide is much less soluble than calcium hydroxide. It is well to wait seventeen minutes after adding the magnesium lime before checking the acidity of the cream. This allows a safety factor of two minutes to insure a complete reaction.

The data in table 2 show the rapidity of the reaction for each neutralizer. The calcium limes react rapidly the first minute and then slower until the complete reaction takes place in four or five minutes. The magnesium limes react with practically the same speed as the calcium limes for the first five minutes and then much slower until the reaction is completed in ten to fifteen minutes. This slowing down is due probably to the complete reaction of the calcium hydroxide after five minutes which leaves the less soluble magnesium hydroxide to react with the acid in the cream.

The mixed neutralizers react very similar to the calcium limes. Six minutes should elapse between the addition of the neutralizer to the cream and the time when the acidity is again determined. It will be noted that the acid reduction is very rapid at first because the soluble neutralizer present reacts immediately, but it takes time for the reaction between the lime and the acid.

The time required for a complete reaction between the neutralizer and the acid in the cream (provided the two are agitated thoroughly) is found in table 2. The average time for all of the neutralizers to react is five and one-half minutes. All of the

classes of neutralizers complete the reaction in five minutes or less except the magnesium limes; these require ten to fifteen minutes.

The reduction in acidity during the pasteurization process

The reduction in acidity which takes place during the pasteurization process is given for each neutralizer in table 3. During this process as well as previous to it, the neutralizers in each group act similarly.

TABLE 3*

Reduction in acidity during the pasteurization process

NEUTRALIZER USED	TIME HELD AFTER NEUTRALIZATION AND BEFORE PASTEURIZATION	REDUCTION DURING PASTEURIZATION IN THE PER CENT ACIDITY
	minutes	*per cent*
Lehigh Lime	15	0.018
Slaked lime	15	0.030
Allwood Lime	15	0.050
Peerless Lime	15	0.040
Kelly Island Lime	15	0.058
Soda ash	15	0.068
Sodium bicarbonate	15	0.075
50–50 Mixture Lehigh Lime and soda ash	15	0.027
50–50 mixture Lehigh Lime and sodium bicarbonate	15	0.047
Average for all		0.046

* This table gives the average of six determinations for each neutralizer.

Most creamery operators depend on some reduction in acidity during pasteurization. Opinions vary as to the amount of this reduction. Some claim that a reduction of only 0.05 per cent is obtained; others state that there is at least a reduction of 0.1 per cent. As a matter of fact, this will be governed by several factors: first, by the neutralizer used; second, whether or not the time allowed between the addition of the neutralizer and the checking of the acidity is long enough; third, the thoroughness of mixing the neutralizer and the cream; and last, the care with which the neutralizing solution is prepared. If the cream and neutralizer are not mixed thoroughly, the reduction in acidity

may not be complete in the time allowed for the reaction, and it will be completed during pasteurization. Thus a greater decrease is shown during pasteurization than would have been the case if the neutralizer and cream had been mixed properly. If the neutralizing solution is not properly prepared and the particles of lime are large, it will take longer for a complete reaction between the lime and the acid in the cream. A fine suspension of lime is most desirable.

The reaction of the calcium limes was complete before pasteurization, since the data show a reduction in acidity during pasteurization of only 0.02 to 0.03 per cent. This reduction may have been due, not so much to completing the action of the lime on the acid, as to the driving off of volatile substances such as carbon dioxide.

The reduction when the magnesium limes were used varied between 0.05 and 0.055 per cent. Possibly, the large reduction was due to the fact that the reaction between the lime and the acid which was brought about more completely by the increased heat. It may have been partially due, also, to the driving off of volatile substances.

The soluble neutralizers gave the largest reduction during pasteurization. It varies between 0.065 and 0.075 per cent. When these neutralizers were added to cream, carbon dioxide was liberated, and in sufficient quantities to cause the cream to foam. The foaminess was more pronounced with sodium bicarbonate than it was with soda ash. Carbon dioxide is soluble in water but rather unstable and is quickly driven off by heat. This accounts for the reduction during pasteurization rather than a further reaction between the neutralizer and the acid in the cream.

The mixed neutralizers reacted as sort of averages between calcium limes and the soluble class. Such reactions might be expected as they contained equal parts of both Lehigh Lime and the soluble neutralizers. There is more reduction than with lime alone and less than with the soluble class. The reduction varies from 0.025 and 0.047 per cent acidity.

The average reduction for all neutralizers was 0.045 per cent.

The calcium limes and the mixed limes gave a reduction less than the average: the soluble neutralizers and the magnesium limes more than the average.

The reduction during the pasteurization process in commercial practice coincides with the work reported above and which was carried out on a small experimental scale. The following figures bear out this evidence. Five equal lots of the same cream were neutralized with Lehigh Lime, Peerless Lime, Slaked Lime, Kelly Island Lime and Allwood Lime. They were pasteurized at 160°F. for fifteen minutes. The acidities prior to pasteurization and after the cream had been held at 100°F. for fifteen minutes with the added neutralizer were: 0.20, 0.21, 0.19, 0.20, and 0.19 per cent, respectively. The acidities after pasteurization were: 0.17, 0.18, 0.16, 0.16, and 0.15 per cent. The reductions were: 0.03, 0.03, and 0.03, 0.04, and 0.04 per cent, respectively. These figures verify the results obtained in the smaller experiments. (The first three are calcium limes and the other two are magnesium limes.)

The relation of the various neutralizers to the butterfat lost in the buttermilk

Tables 4 and 5 gives the results of the various neutralizers on the butterfat lost in the buttermilk. The neutralizers are grouped as individual neutralizers, similar neutralizers, and in the various combinations.

Whenever soda ash was used, either by itself or with Lehigh Lime, the test of buttermilk was the highest. In table 4, the average for all individual neutralizers was 0.701 per cent butterfat. The soda ash gave results from 0.086 to 0.134 per cent above this average. This is to be expected for soda ash tends to saponify the fat and also stabilize an emulsion. Either of these factors would account for a higher fat loss in the buttermilk.

Sodium bicarbonate did not give the same results as soda ash. The fat losses were below the average for all individual neutralizers except in one case. When Lehigh Lime and sodium bicarbonate were mixed before they were added to the cream the fat loss was greater than when they were used separately; yet it

was only slightly above the average for all or 0.011 per cent for five determinations. Excess fat losses did not result from the use of sodium bicarbonate as was the case when soda ash was used.

TABLE 4

The relation of the various neutralizers to the butterfat lost in the buttermilk and the time to churn

NUMBER OF CHURNINGS	NEUTRALIZER	ACIDITY OF THE CREAM AT START	ACIDITY OF THE CREAM TO CHURN	TEST OF THE BUTTERMILK	TEST OF THE BUTTERMILK ABOVE OR BELOW THE AVERAGE FOR ALL CHURNINGS	TIME TO CHURN IN MINUTES
33	Average of all combined.....	0.54	0.22	0.701	0.000	16.0
	The individual neutralizers					
2	Kelly Island Lime	0.54	0.22	0.620	−0.081	16.5
2	Slaked lime	0.54	0.21	0.650	−0.051	15.5
2	Allwood Lime	0.54	0.22	0.595	−0.106	15.5
2	Peerless Lime	0.54	0.225	0.580	−0.121	16.0
5	Lehigh Lime	0.50	0.24	0.638	−0.063	17.2
3	Soda ash	0.47	0.21	0.787	+0.086	16.5
3	Sodium bicarbonate	0.47	0.21	0.680	−0.021	17.5
5	50–50 mixture Lehigh Lime and soda ash	0.55	0.22	0.794	+0.093	16.1
5	50–50 mixture Lehigh Lime and sodium bicarbonate	0.55	0.22	0.712	+0.011	16.2
2	Lehigh Lime to 0.4 per cent and soda ash to 0.2 per cent acidity	0.65	0.20	0.835	+0.134	15.0
2	Lehigh Lime to 0.4 per cent and sodium bicarbonate to 0.2 per cent acidity	0.65	0.20	0.630	−0.071	14.5
	Similar neutralizers					
6	Soluble	0.47	0.21	0.733	+0.032	17.0
14	Mixed	0.58	0.215	0.748	+0.047	15.1
9	Calcium limes	0.52	0.22	0.649	−0.052	16.6
4	Magnesium limes	0.55	0.22	0.607	−0.094	15.7

The use of soda ash resulted in the highest fat losses, the sodium bicarbonate was about the average and the other extreme was obtained when limes were used. In each case, the limes were

TABLE 5

The relation of the various neutralizers to the butterfat lost in the buttermilk and the time to churn

Various combinations

NUMBER OF CHURNINGS	NEUTRALIZER	ACIDITY OF THE CREAM AT START	ACIDITY OF THE CREAM TO CHURN	TEST OF THE BUTTERMILK	TEST OF THE BUTTERMILK ABOVE OR BELOW THE AVERAGE FOR ALL CHURNINGS	TIME TO CHURN
						minutes
2	Kelly Island Lime	0.54	0.22	0.620	−0.110	16.5
2	Lehigh Lime	0.54	0.23	0.615	−0.115	16.5
2	Allwood Lime	0.54	0.22	0.595	−0.135	15.0
2	Peerless Lime	0.54	0.225	0.580	−0.150	16.0
2	Slaked lime	0.54	0.21	0.650	−0.080	15.5
2	50–50 mixture Lehigh Lime and soda ash	0.475	0.22	0.785	+0.055	16.0
2	50–50 mixture Lehigh Lime and sodium bicarbonate	0.475	0.215	0.840	+0.110	16.5
2	Lehigh Lime	0.475	0.21	0.730	0.000	18.5
2	Soda ash	0.475	0.20	0.890	+0.160	17.5
2	Sodium bicarbonate	0.475	0.215	0.760	+0.030	18.5
2	Lehigh Lime	0.54	0.23	0.615	−0.115	16.5
2	Peerless Lime	0.54	0.225	0.580	−0.150	16.0
2	Slaked lime	0.54	0.21	0.650	−0.080	15.5
3	Lehigh Lime	0.47	0.21	0.653	−0.077	17.6
3	Soda ash	0.47	0.21	0.786	+0.056	16.5
3	Sodium bicarbonate	0.47	0.21	0.680	−0.050	17.5
2	Allwood Lime	0.54	0.22	0.595	−0.135	15.0
2	Kelly Island Lime	0.54	0.22	0.620	−0.110	16.5
2	50–50 mixture Lehigh Lime and sodium bicarbonate	0.65	0.22	0.625	−0.105	15.5
2	To 0.4 per cent with Lehigh Lime to 0.2 per cent with sodium bicarbonate	0.65	0.20	0.630	−0.100	14.5
4	50–50 mixture Lehigh Lime and soda ash	0.52	0.20	0.973	+0.243	16.4
4	50–50 mixture Lehigh Lime and sodium bicarbonate	0.52	0.20	0.973	+0.243	16.2

TABLE 5—*Continued*

NUMBER OF CHURNINGS	NEUTRALIZER	ACIDITY OF THE CREAM AT START	ACIDITY OF THE CREAM TO CHURN	TEST OF THE BUTTERMILK	TEST OF THE BUTTERMILK ABOVE OR BELOW THE AVERAGE FOR ALL CHURNINGS	TIME TO CHURN
						minutes
2	To 0.4 per cent with Lehigh Lime to 0.2 per cent with soda ash	0.65	0.205	0.835	+0.105	19.0
2	To 0.4 per cent with Lehigh Lime to 0.2 per cent with sodium bicarbonate	0.65	0.20	0.630	−0.100	18.5
2	50–50 mixture Lehigh Lime and soda ash	0.65	0.225	0.840	+0.110	15.0
2	To 0.4 per cent with Lehigh lime to 0.2 per cent with soda ash	0.65	0.19	0.835	+0.105	14.0
59	Average for all	0.539	0.212	0.730	0.000	16.4

below the average for all or 0.701 per cent. They varied from 0.051 to 0.121 per cent below.

The same general results are found when the groups of neutralizers are considered. The limes were below the average and the mixed and soluble groups were above. The mixed and soluble groups contained both soda ash and sodium bicarbonate.

Table 5 gives results which are comparable to those given in table 4.

The time to churn is not greatly affected by any one neutralizer.

Relation of the various neutralizers on the score of the fresh butter and on its keeping quality during storage

The score of the fresh butter made with each neutralizer and the change in score during storage periods of thirty days, sixty days and ninety days are found in table 6.

In this table, the various neutralizers are grouped under lot numbers. Each churning in a lot was made from the same cream and under identical conditions except for the neutralizer.

TABLE 6

A comparison of the scores of fresh and storage butters made with the same neutralizer

LOT NUMBER	NEUTRALIZER USED	SCORE OF THE BUTTER				CHANGE IN SCORE FROM THE FRESH BUTTER IN			REMARKS
		Fresh	Thirty days	Sixty days	Ninety days	Thirty days	Sixty days	Ninety days	
Series A. Each lot made from the same cream									
1	Kelly Island Lime	88.00	87.50	86.50	84.00	0.50	1.50	4.00	Flat, sweet flavor*
	Lehigh Lime	88.00	87.00	86.00	83.00	1.00	2.00	5.00	
	Allwood Lime	88.00	87.50	86.50	84.00	0.50	1.50	4.00	Same as in Kelly Island Lime*
	Peerless Lime	88.00	87.00	86.00	84.00	1.00	2.00	4.00	
	Slaked lime	88.00	85.50	85.00	83.00	2.50	3.00	5.00	Limy flavor
2	Kelly Island Lime	89.50	89.00	87.50	85.50	0.50	2.00	4.00	Sweet flavor
	Lehigh Lime	89.50	88.50	87.50	85.00	1.00	2.00	4.50	
	Allwood Lime	89.50	88.75	87.00	85.00	0.75	2.50	4.50	Flat, sweet flavor
	Peerless Lime	89.50	88.50	87.00	84.50	1.00	2.50	5.00	
	Slaked lime	89.50	88.25	86.50	84.00	1.25	3.00	5.50	
3	Lehigh Lime	88.00	87.00	86.00	83.00	1.00	2.00	5.00	
	Peerless Lime	88.00	87.00	86.00	84.00	1.00	2.00	4.00	
	Slaked lime	88.00	85.50	85.00	83.00	2.50	3.00	5.00	Limy flavor
4	Lehigh Lime	89.50	88.50	87.50	85.00	1.00	2.00	4.50	
	Peerless Lime	89.50	88.50	87.00	84.50	1.00	2.50	5.00	
	Slaked lime	89.50	88.25	86.50	84.00	1.25	3.00	5.50	

5	Kelly Island Lime	88.00	87.50	86.50	84.00	0.50	1.50	4.00	Flat, sweet flavor
	Allwood Lime	88.00	87.50	86.50	84.00	0.50	1.50	4.00	Flat, sweet flavor
6	Kelly Island Lime	89.50	89.00	87.50	85.50	0.50	2.00	4.00	Sweet flavor
	Allwood Lime	89.50	88.75	87.00	85.00	0.75	2.50	4.50	Flat, sweet flavor
	Series B. Each lot made from the same cream								
7	Lehigh Lime	89.50	87.00	86.25	86.00	2.50	3.25	3.50	
	Soda ash	88.75	87.50	86.25	86.00	1.25	2.50	2.75	
	Sodium bicarbonate	88.50	87.50	86.25	86.00	1.00	2.25	2.50	
8	Lehigh Lime	90.00	90.00	89.00	87.50	0.00	1.00	2.50	
	Soda ash	90.00	90.00	89.00	85.00	0.00	1.00	5.00	Rancid in ninety days
	Sodium bicarbonate	89.00	88.50	88.00	85.25	0.50	1.00	3.75	Bicarbonate flavor
9	Lehigh Lime	90.50	89.00	87.50	84.00	1.50	3.00	6.50	
	Soda ash	90.50	89.00	88.00	85.00	1.50	2.50	5.50	Rancid in ninety days
	Sodium bicarbonate	90.00	89.00	88.00	83.00	1.00	2.50	7.00	Bicarbonate flavor
	Series C. Each lot made from the same cream								
10	50–50 mixture Lehigh Lime and soda ash	89.50	88.50	88.00	86.00	1.00	1.50	3.50	
	50–50 mixture Lehigh Lime and sodium bicarbonate	89.00	87.00	86.50	85.00	2.00	2.50	4.00	Bicarbonate flavor
	Lehigh Lime	90.00	90.00	89.00	87.50	0.00	1.00	2.50	
	Soda ash	90.00	90.00	89.00	85.00	0.00	1.00	5.00	Rancid in ninety days
	Sodium bicarbonate	89.00	88.50	88.00	85.25	0.50	1.00	3.75	Bicarbonate flavor

TABLE 6—*Continued*

LOT NUMBER	NEUTRALIZER USED	SCORE OF THE BUTTER				CHANGE IN SCORE FROM THE FRESH BUTTER IN			REMARKS
		Fresh	Thirty days	Sixty days	Ninety days	Thirty days	Sixty days	Ninety days	
	Series C. Each lot made from the same cream—continued								
11	50–50 mixture Lehigh Lime and soda ash	89.50	88.50	88.00	83.00	1.00	1.50	6.50	Old, Rancid in ninety days
	50–50 mixture Lehigh Lime and sodium bicarbonate	89.00	88.00	87.00	84.00	1.50	2.00	5.00	Bicarbonate flavor
	Lehigh Lime	90.50	89.00	87.50	84.00	1.50	3.00	6.50	
	Soda ash	90.50	89.00	88.00	85.00	1.50	2.50	5.50	Rancid in ninety days
	Sodium bicarbonate	90.00	89.00	88.00	83.00	1.00	2.50	7.00	
	Series D. Each lot made from the same cream								
12	50–50 mixture Lehigh Lime and soda ash	86.50	84.00	80.00	†	2.50	6.50	†	Rancid in sixty days
	To 0.4 per cent with Lehigh Lime to 0.2 per cent with soda ash	87.50	85.00	84.00	†	2.50	3.50	†	
13	50–50 mixture Lehigh Lime and soda ash	88.00	87.50	84.00	†	0.50	4.00	†	
	To 0.4 per cent with Lehigh Lime to 0.2 per cent with soda ash	89.00	88.00	85.00	†	1.00	4.00	†	
14	50–50 mixture Lehigh Lime and sodium bicarbonate	87.50	83.00	77.00	†	4.50	10.5	†	
	To 0.4 per cent with Lehigh Lime to 0.2 per cent with sodium bicarbonate	89.00	88.00	85.00	†	1.00	4.00	†	

15	50–50 mixture Lehigh Lime and sodium bicarbonate	87.00	84.00	81.00	†	3.00	6.00	†	
	To 0.4 per cent with Lehigh Lime to 0.2 per cent with sodium bicarbonate	87.25	86.00	85.00	†	1.25	2.25	†	
	Series E. Each lot made from the same cream								
16	50–50 mixture Lehigh Lime and soda ash	89.50	88.50	87.00	85.00	1.00	2.50	4.50	
	50–50 mixture Lehigh Lime and sodium bicarbonate	88.50	87.00	86.75	86.00	1.50	1.75	2.50	Bicarbonate flavor
17	50–50 mixture Lehigh Lime and soda ash	89.50	88.50	88.00	86.00	1.00	1.50	3.50	
	50–50 mixture Lehigh Lime and sodium bicarbonate	89.00	87.00	86.50	86.00	2.00	2.50	3.00	Bicarbonate flavor
18	50–50 mixture Lehigh Lime and soda ash	89.50	88.50	88.00	83.00	1.00	1.50	6.50	Rancid after ninety days
	50–50 mixture Lehigh Lime and sodium bicarbonate	89.00	88.00	87.00	84.00	1.00	2.00	5.00	
19	To 0.4 per cent with Lehigh Lime to 0.2 per cent with soda ash	88.50	85.00	84.00	†	3.50	4.50	†	
	To 0.4 per cent with Lehigh Lime to 0.2 per cent with sodium bicarbonate	88.25	86.00	85.00	†	1.25	3.25	†	
20	To 0.4 per cent with Lehigh Lime to 0.2 per cent with soda ash	89.00	88.00	85.00	†	1.00	4.00	†	
	To 0.4 per cent with Lehigh Lime to 0.2 per cent with sodium bicarbonate	89.00	88.00	85.00	†	1.00	4.00	†	

* Mottled after ninety days.

† Discontinued after sixty days storage because of poor quality.

The table is divided into five series. Each one contains the results secured with certain groups of neutralizers in the same cream. They are arranged so that comparisons are interchangeable between series, for a certain neutralizer is found in more than one.

Since one cream may produce a better quality butter than another, even though they both may appear to be similar as determined by taste and smell, the cream used in this series of determinations was selected so as to minimize this condition. The cream was taken from that received at a large commercial creamery, and was of fairly good quality. The acidity varied from 0.47 to 0.65 per cent and the butterfat from 29 to 34 per cent. The acidity was reduced to approximately 0.2 per cent and no starter was added.

The results show that there was very little advantage gained as far as the quality of the fresh butter was concerned by the use of one neutralizer over the other when each was used by itself. But when a combination was used, either together or separately, the score of the fresh butter was not as high as when a single neutralizer was used. On the other hand, when the acidity was reduced to 0.4 per cent with lime and then to 0.2 per cent with soda ash or sodium bicarbonate, the quality of the fresh butter was better than when the two were mixed before they were added to the cream.

In comparing the use of lime and soda ash or sodium bicarbonate for reducing the acidity of the cream, the same general quality of cream was used as with all other neutralizers. Many creameries make a practice of using one certain neutralizer except for cream which is extremely high in acid, as 0.8 per cent and above. In such cases, the acidity is reduced to a given point with lime and the balance with a soda ash or a sodium bicarbonate solution. This method does tend to eliminate a limy or soapy flavor which would ordinarily occur, if one neutralizer was used.

The limes and soda ash produced fresh butter which was similar in quality. The sodium bicarbonate butter scored slightly lower than the soda ash or the limes because of a bicarbonate

flavor which was detected in the butter whenever it was used. The mixtures of lime and the soluble neutralizers resulted in a lower score than when only one was used.

Another interesting fact is brought out in table 6. In each series where soda ash and sodium bicarbonate were used in the same cream, either separately or with lime, the fresh butter made with the former scored higher than that made with the latter. It seems impossible to make butter from cream neutralized with sodium bicarbonate without securing the bicarbonate flavor in the fresh butter. After storage periods of thirty, sixty and ninety days, the butter was scored again by the same judge. The reduction in score for the soda ash was greater than for the sodium bicarbonate in each series. In most cases the score of the fresh butter made with sodium bicarbonate was a quarter to one point lower than that made with soda ash, but after sixty to ninety days, the score was the same or above that made with soda ash. This would tend to indicate that butter made with soda ash does not retain its quality during storage as well as that made with sodium bicarbonate. In each case where rancidity developed during storage, soda ash had been used as the neutralizer. Possibly, this can be explained in that soda ash is a stronger alkali and causes a more rapid chemical breakdown of the butterfat. More data are necessary before positive conclusions can be drawn stating that butter made with soda ash as a neutralizer, will not store as well as that made with sodium bicarbonate.

The neutralizers did not have any effect on the body of the butter except in one series. In lot 1, mottles were noticed where Kelly Island Lime and Allwood Lime had been used. The cause was not determined, although this condition was not noticeable until after ninety days storage.

The butter made with a combination (lots 12, 13, 14, 15, 19 and 20) of neutralizers was not scored after sixty days as they were discarded because the scores had dropped to 85 or below. The others were held for ninety days.

In comparing the various limes, it can not be said that one has an advantage over the other as far as score is concerned. Series

A shows that the fresh butter for each lot was the same. In thirty and sixty days time all were practically the same except the slaked lime, and it was slightly lower and showed a limy flavor. Another outstanding fact was that a flat, sweet flavor was noticed in each case where a magnesium lime had been used. Although this flavor was present, it did not lower materially the score as compared with the calcium limes. From the data obtained, it can be said that no one lime has an advantage over another if each is handled properly.

In series B experiments, the soluble neutralizers were compared with lime. The data show that neither has a decided advantage over the other. As far as the fresh butter was concerned, all were the same except for the flavor found when sodium bicarbonate was used, which reduces the score slightly. After storage (three lots), no one neutralizer seemed to be best. In one case, the lime held up best; in another, the soda ash; and in the third, the sodium bicarbonate.

SUMMARY

1. A better quality of fresh butter and a more exhaustive churning was secured with a 5 per cent solution of soda ash or sodium bicarbonate, and a 10 per cent solution of a lime than with a stronger solution of these neutralizers.

2. The time required for a complete reaction between the acid in the cream and the neutralizer after its addition, varied with the neutralizers. The soluble neutralizers reacted completely in two minutes; the calcium limes in five minutes; and the magnesium limes in ten to fifteen minutes.

3. The reduction in acidity during pasteurization varied with the neutralizer. The maximum reduction with the soluble neutralizers was 0.75 per cent; with the calcium limes, 0.04 per cent; and with the magnesium limes, 0.058 per cent. The reduction seemed to depend on the solubility of the neutralizer and also upon the formation of carbon dioxide gas which was driven off by heat.

4. No definite rule can be formulated as to the effect the neutralizers had on the time of churning.

5. The use of soda ash increased the fat lost in the buttermilk; while the sodium bicarbonate and the limes gave a more exhaustive churning with the latter more efficient than the former.

6. No one of the neutralizers tried (lime, soda ash or sodium bicarbonate) can be said to produce the best quality of fresh butter. The sodium bicarbonate tended to reduce the score slightly because of a slight bicarbonate flavor which was always present in the butter.

7. The separate neutralizers gave a higher score butter than when two were used together, either separately or mixed before they were added to the cream.

8. When lime and soda ash or sodium bicarbonate were used, the best results were gained by using them separately rather than mixing them, with the lime used first.

9. When soda ash entered into the neutralizer, either by itself or with lime, the butter was of a higher quality at the start but it did not hold up as well in storage as did the butter in which sodium bicarbonate was used as a neutralizer, either by itself or with lime.

10. In each case where rancidity developed after storage, soda ash had been used as the neutralizer.

11. No one lime had an advantage over the others, either for fresh or storage butter, when all were handled properly.

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RELATIVE RATES OF SECRETION OF VARIOUS MILK CONSTITUENTS*

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If we take a unit quantity of natural cow's milk, that is, the entire milk as obtained from the cow during a period of some length under normal conditions, we know that it may be separated on a chemical basis into several component parts. The constituents of milk customarily determined by the chemist, are, in order of their average magnitude per unit of milk: water, lactose, fat, protein and ash. A great many analyses of milk have been made on this basis, from various points of interest. The chemist has been interested from the standpoint of the composition of the milk; the food inspector, from the standpoint of food values, abnormalities or adulterations of the milk; and the biologist, from the standpoint of the physiological mechanism and requirements of milk secretion. From the latter standpoint the work of T. L. Haecker in formulating a feeding standard for dairy cows constitutes a notable example.

Haecker (1) has published the analyses of 543 samples of milk and derived certain conclusions from the data particularly with reference to the feed requirements for milk production. The analyses give the per cent of fat, protein, lactose, ash and dry matter. Fat was determined in part gravimetrically and in part by the Babcock method; protein, dry matter and ash gravimetrically; lactose, by difference. Each of the 543 samples represents the milk of an individual cow for one week, fourteen milkings. The samples were taken at various stages of lactation and under various conditions of experimental feeding, reference especially to the nutritive ratio of the ration. Fifty-two cows of various ages, weights and breeding are represented: ages, two to fourteen years; weights, 600 to 1350 pounds; breeding, natives and pure-

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breds, grades or cross-breds of the Ayrshire, Brown Swiss, Guernsey, Hereford, Holstein, Jersey and Shorthorn breeds. Altogether, these analyses constitute a unique and valuable body of accurate data on the constituents of cows' milk and it has seemed desirable to study the relations which they show by the usual statistical methods.

CORRELATION BETWEEN THE MILK CONSTITUENTS

In correlating the percentage values of the several constituents class intervals were used as follows: water, 0.5; fat, 0.2; protein, 0.2; lactose, 0.1; ash, 0.02. The means, standard derivations and coefficients of variability are given in table 1. The significance of these constants is practically limited to the present data be-

TABLE 1

Values of the percentage content of the various constituents of the 543 weekly milk yields

CONSTITUENT	MEAN	STANDARD DEVIATION	COEFFICIENT OF VARIABILITY
Water	86.303±0.044	1.524±0.031	1.77±0.04
Lactose	4.888±0.007	0.259±0.005	6.65±0.11
Fat	4.731±0.029	0.998±0.020	21.10±0.43
Protein	3.349±0.014	0.488±0.010	14.57±0.30
Ash	0.723±0.001	0.049±0.001	6.84±0.14

cause of the throwing together of several breeds in very dissimilar porportions of the total, as to numbers. The coefficients of variability in fat, protein, lactose and ash are about double what we should expect to find in any one breed (cf. Yapp (2)). As measured by this coefficient water is by far the least variable of the five constituents of the milk as determined, while fat is the most variable. The standard deviation of the water, however, exceeds that of the fat.

It is possible to compute ten simple correlations between the five constituents determined. These are given in table 2 in order of the absolute magnitude of the coefficients. It may be noted that there is a great difference in the values of the coefficients, three of them being remarkably high, while all the others are rather low, although statistically significant as judged by the

probable errors. It may be noted also that the four coefficients involving water are all negative while those between the solid constituents are all positive except that between lactose and ash.

TABLE 2

Correlation between the relative average rates of secretion of the various milk constituents for the 543 weekly periods

VALUES CORRELATED	COEFFICIENTS OF CORRELATION
Fat per cent and water per cent	-0.966 ± 0.002
Protein per cent and water per cent	-0.885 ± 0.006
Protein per cent and fat per cent	$+0.812 \pm 0.010$
Lactose per cent and water per cent	-0.386 ± 0.025
Protein per cent and ash per cent	$+0.325 + 0.026$
Ash per cent and water per cent	-0.264 ± 0.027
Fat per cent and lactose per cent	$+0.263 \pm 0.027$
Fat per cent and ash per cent	$+0.232 \pm 0.027$
Protein per cent and lactose per cent	$+0.149 \pm 0.028$
Lactose per cent and ash per cent	-0.140 ± 0.028

TABLE 3

Interrelational equations for several milk constituents, derived from the constants of Tables 1 and 2

a = ash per cent; f = fat per cent; l = lactose per cent p = protein per cent; s = solids per cent; $s\text{-}n\text{-}f$ = solids-not-fat per cent; w = water per cent.

The probable errors are for a single variate.

BASED ON FAT PER CENT	BASED ON PROTEIN PER CENT
$a = (0.671 + 0.011f) \pm 0.032$	$a = (0.613 + 0.033p) \pm 0.032$
$p = (1.46 + 0.40f) \pm 0.19$	$f = (1.66p - 0.83) \pm 0.39$
$l = (4.56 + 0.07f) \pm 0.17$	$l = (4.62 + 0.08p) \pm 0.17$
$s = 6.74 + 1.47f$	$s = 4.45 + 2.76p$
$s\text{-}n\text{-}f = 6.74 + 0.47f$	$w = (95.55 - 2.76p) \pm 0.48$
$w = (93.26 - 1.47f) \pm 0.27$	

THE REGRESSION EQUATIONS

The regression equations, computed from the constants of tables 1 and 2 are given in table 3 with reference to the regression of the several constituents on fat percentage and protein percentage. Figures 1 and 2 show graphically the curves of the equations and the mean observed values. It is apparent from the plotted values that the regressions are substantially linear in

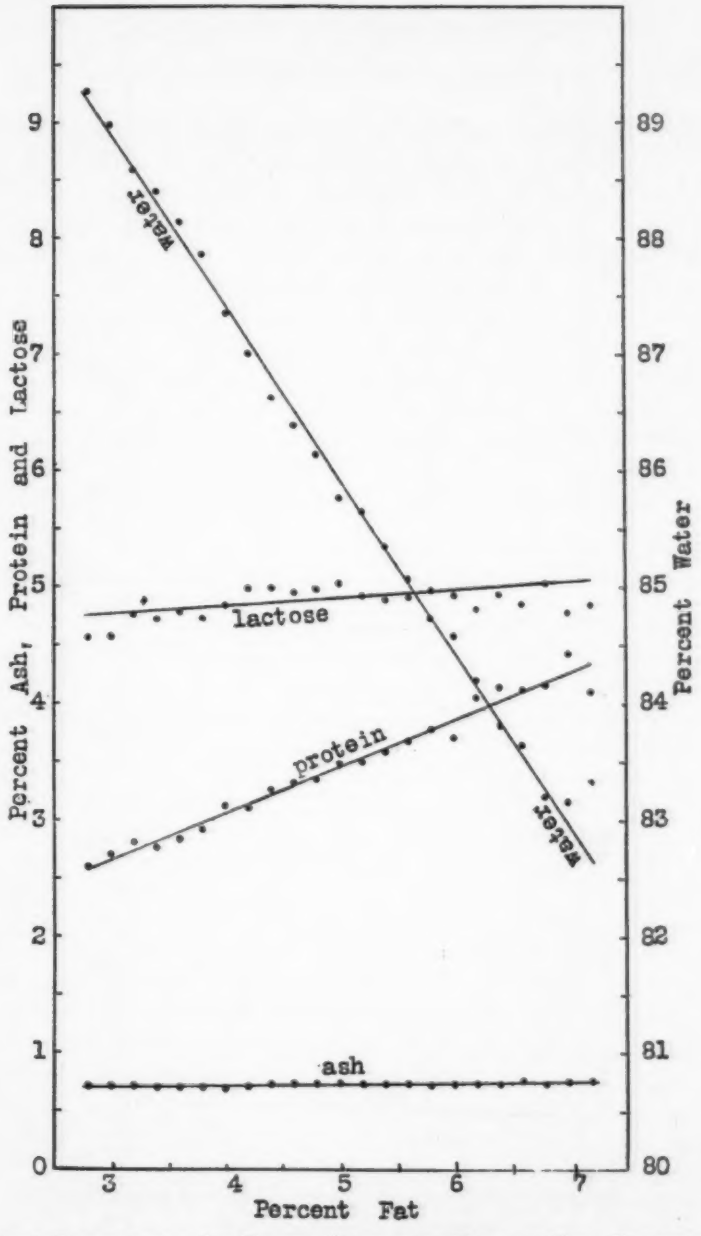

FIG. 1. REGRESSION OF ASH, PROTEIN, LACTOSE AND WATER ON FAT. EQUATIONS TO STRAIGHT CURVES IN TABLE 3

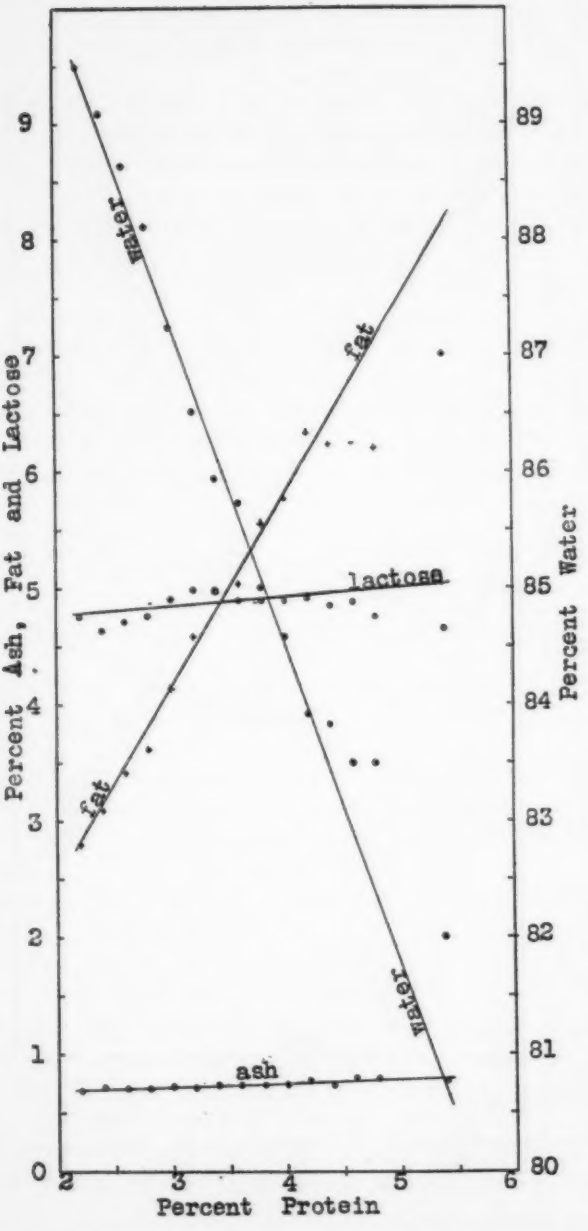

FIG. 2. REGRESSION OF ASH, FAT, LACTOSE AND WATER ON PROTEIN. EQUATIONS TO STRAIGHT CURVES IN TABLE 3

all cases, although that for lactose seems to have a slight tendency to a concave downward curvature. It seems also that in general there is a tendency for the regressions on fat percentage to be rather more regular than on protein percentage.

The equation, $p = (1.46 + 0.40f) \pm 0.19$ is of particular interest. Timpe (3) from analyses of milk from 21 cows of various breeds derived the relation $p = 2 + 0.35f$. Andersen and Langmack (4) from 1080 analyses of the milk of Red Danish cows derived the equation $p = 1.597 + 0.446f$. They have rounded this into $p = 1.4 + 0.5f$, thus increasing the slope or ratio of protein change to fat change. From the evidence available it would seem that their ratio was already somewhat high as expressing the general relation (cf. fig. 3) and might better have been decreased rather than increased.

RELATIVE RATES OF SECRETION OF VARIOUS CONSTITUENTS

The records of composition as previously stated, represent for any one sample the entire milk produced by an individual cow during seven consecutive days. While they give no information as to the *absolute* amount of milk or its several constituents secreted during the period, they do show the *relative* amounts of the several constituents of the milk secreted during the period. If any two constituents of milk are intimately related in the mechanism of milk secretion, so that when the rate of secretion of one increases the rate of the other increases accordingly then values of these two as expressed in percentage composition of the various samples of milk will tend to bear to each other a constant ratio. Under these conditions the data as above treated would give a high positive correlation between any two constituents so related. Conversely, a high positive correlation between any two constituents indicates that the two are in some manner intimately connected in the physiological processes of secretion.

A high negative correlation need not have a similar meaning. If we consider the solids and water of milk obviously r_{sw} must equal -1. If the secretion of each of the five milk constituents we are considering proceeds entirely independently then we should expect to find a negative correlation between any two constit-

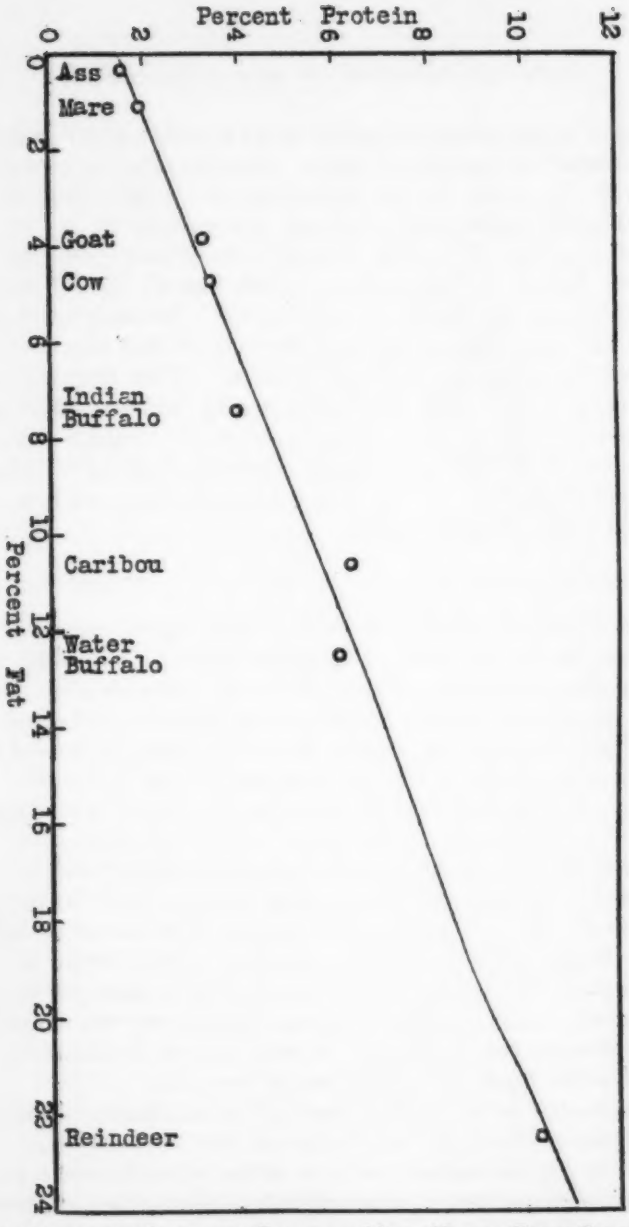

FIG. 3. RELATION OF PROTEIN TO FAT IN THE MIXED MILK OF EIGHT SPECIES OF MAMMALS

The straight curve expresses the relation as found between individual cows

uents. Consequently, the negative correlations do not have the same significance as the positive correlations.

It will be understood, of course, that the chemical distinctions made in the series of analyses under discussion are not necessarily sufficiently fine to show all of the physiological relations that may be susceptible of elucidation through quantitative chemical analysis. One of the five constituents represents a single compound, that is, water. Lactose perhaps represents also a distinct compound but as determined, by difference, there is some uncertainity as to this. The other three represent more or less complex mixtures.

The most significant positive correlation is that between fat

TABLE 4

Relation of fat and protein in the milk of several species of mammals—average data selected as representative of the normal secretion

SPECIES	PER CENT FAT	PER CENT PROTEIN	AUTHORITY
Ass	0.36	1.57	Schlossman (5)
Mare	1.09	1.89	Vieth (6)
Goat	3.82	3.21	Bosworth and Van Slyke (7)
Cow	4.73	3.35	Haecker (1)
Indian buffalo	7.41	3.89	Leather (8)
Caribou	10.63	6.31	Musgrave and Richmond (9)
Water buffalo	12.46	6.04	Levine (10)
Reindeer	22.46	10.30	Barthel and Bergman (11)

and protein. The secretion of the materials involved in these two catagories must be quite intimately related. Further, this relation seems to be a general phenomenon of milk secretion since substantially the same relation between the rate of fat secretion and protein secretion is found between widely separated species of mammals. It is true that a great many analyses of milk of various mammals as reported in the literature do not show the same relation as shown above for the cow. For the comparison under study it is necessary, however, to be somewhat discriminating about how well the sample analysed actually represents the total amount of milk secreted by a particular individual or group of individuals during a certain period. Milk is very subject to disturbance in homogeneity with respect to its fat content. The

force of gravity or passage of the milk through the fine spaces of the gland readily alter the fat concentration in the various fractions of the milk. For this reason many fat determinations are undoubtedly very misrepresentative of the true activity of the mammary gland. If the fat determination is not representative the fat-protein ratio is, of course, misleading. Among those mammals which are regularly milked as a commercial source of milk we may expect to be able to obtain samples which are truly representative of the activity of the mammary gland. While there are no data for mammals other than the cow comparable with that of Haecker in extent and reliability, the analyses summarized in table 4 seem from the authors' accounts to be fairly representative of the normal secretion.

The data of table 4 are given graphically in figure 3 together with the curve, derived from Haecker's analyses of milk from individual cows. It is certainly very striking that this relation between fat and protein should hold so closely in other species and through so wide a range of fat percentage—0.36 per cent in the ass to 22.46 per cent in the reindeer. It gives greater significance to the relation in connection with the general physiology of milk secretion.

The high negative correlation between water and fat is to be interpreted as indicating that the secretion of water and fat are not physiologically connected. The same interpretation is to be applied to the high negative correlation between water and protein. That is, the secretion of water is largely independent of the secretion of fat or protein, where the general level of activity of the gland is constant.

The same line of reasoning requires the interpretation that the secretion of water and the secretion of lactose and ash are interdependent—otherwise water should show a negative correlation of substantially the same magnitude in the case of each of the four other constituents.

A more refined and detailed chemical analysis is required to give an acceptable picture of the relations between water, lactose, and ash secretion. For, it is apparent from the work of Jackson and Rothera (12) that a sufficiently fine distinction in the deter-

mination of the ash constituents would show a high negative correlation between lactose and portions of the ash. The gross distinctions of the present analyses can be no more than suggestive of fundamental relationships.

SUMMARY

Chemical analyses of 543 samples of milk of individual cows of various breeds published in Minnesota Bulletin 140 are analysed statistically. The results are interpreted physiologically as showing the relative ratios of secretion of the several constituents at a constant level of activity of the mammary gland. The secretion of fat and protein appear to be intimately related; $r_{fp} = 0.812 \pm 0.010$. The secretion of water and the secretion of fat or protein are largely independent on the basis that entire independence would result in a high negative coefficient of correlation;

$$r_{wf} = -0.966 \pm 0.002 \text{ and } r_{wp} = -0.885 \pm 0.006$$

The equation for protein per cent (p) based on fat per cent (f) is $p = (1.46 + 0.40f) \pm 0.19$. This relation appears to hold very closely also between several species, covering a range of fat percentage from 0.36 to 22.46.

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KEEPING QUALITY OF SWEET CREAM BUTTER AS AFFECTED BY TEMPERATURE OF PASTEURIZATION OF THE CREAM

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Butter made from unripened pasteurized sweet cream, commonly termed sweet cream butter, has won the approval of manufacturers, dealers, and consumers because of its fine, mild flavor, its uniformity, and its superior keeping quality. Butter of this type is made largely in creameries where the vat method of pasteurization is used. The prevailing temperature is 145°F. and the time of heating thirty minutes, though in some plants higher temperatures have been used.

In order to determine the effect of the pasteurizing temperature on the keeping quality of sweet cream butter, cream was pasteurized at the following temperatures and samples of the butter were held in storage at about 0°F. for seven and one-half to nine months:

145°F. for 25 minutes
145°F. for 30 minutes
150°F. for 30 minutes
155°F. for 30 minutes
145° to 165°F. for 30 minutes

In pasteurizing at 145° to 165°F. for thirty minutes the cream was heated in the usual way to 145°F., then heated more slowly so that thirty minutes was required to raise the temperature to 165°F. It was then cooled as quickly as possible to churning temperature.

One hundred and sixteen churnings were made between May 23 and August 19, 1924, at two creameries in Minnesota that were

[1] The authors wish to express their appreciation of the assistance in this work of A. Kristensen and Frank W. Logan, Navy butter supervisors; O. O. Vaughn, operator of the Brownton Coöperative Creamery, Brownton, Minnesota, and W. B. Steinhouse, operator of the New Richland Coöperative Creamery, New Richland, Minnesota.

making butter on a Navy contract. The different pasteurizing temperatures were used on different vats of cream; the cream was closely graded and the vats of cream were so uniform that using split batches was not considered necessary.

All the samples used were from churnings accepted on the Navy contract and all were scored when fresh 95 points on a basis of sweet cream butter.

All samples were packed in 5-pound lacquered tin cans and were shipped with other butter in refrigerator freight cars to the

TABLE 1

PASTEURIZING TEMPERATURE		NUMBER OF CHURNINGS	ACIDITY OF CREAM, AVERAGE	WATER IN BUTTER, AVERAGE	SALT IN BUTTER, AVERAGE	AVERAGE SCORE AFTER STORAGE
Degrees Fahrenheit	Minutes					
Creamery no. 1						
			per cent	*per cent*	*per cent*	
145	25	8	0.1810	13.4	2.93	94
145	30	8	0.1808	13.4	2.92	94
150	30	9	0.1850	13.41	3.01	94
155	30	11	0.1902	13.33	2.96	94
145–165	30	6	0.1880	13.47	2.96	94
Creamery no. 2						
145	25	17	0.191	13.38	2.93	92.94
145	30	12	0.202	13.39	2.97	92.83
150	30	14	0.195	13.40	2.93	93.00
155	30	15	0.201	13.36	3.02	93.00
145–165	30	16	0.181	13.39	3.03	93.06

Naval Operating Base, Hampton Roads, Virginia, where they were immediately placed in cold storage and kept there until April 1, 1925.

After they were out of storage for one day they were scored by a commercial judge of recognized ability.

Table 1 shows the scores of the samples for the different pasteurizing temperatures, also the acidity of the cream and the water and salt content of the butter.

This table shows that the samples of butter from Creamery no. 1 after storage were so uniform in quality that they all received the same score; at the other creamery the difference

in score was so slight that it does not indicate the superiority of one group of samples over another.

SUMMARY

In the manufacture of 116 churnings of sweet cream butter for storage, cream was pasteurized at 145°F. for twenty-five minutes, 145°F. for thirty minutes, 155°F. for thirty minutes, and 145° to 165°F. for thirty minutes. Samples of the butter were stored at 0°F. for seven and one-half to nine months. Scores of the butter after storage indicate the keeping quality was not influenced by these temperatures of pasteurization of the cream.

RELATION BETWEEN THE GOLD NUMBER OF GELATIN AND ITS VALUE IN THE ICE CREAM MIX*

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The gold number has been used by chemists for twenty-five years as a means of measuring the protective property of colloids, but this method has never been applied to the grading of gelatin to be used in the manufacture of ice cream. Thomas (6) (1925) says, "The gold numbers are useful, however, solely as very rough indices of the relative protective powers, because the gold number of a given protective colloid depends so largely upon many conditions." Elliott and Sheppard (3) (1921) studied the gold numbers of seventeen different samples of commercial gelatins and concluded from their study that the classification made possible by the gold numbers was too rough, and moreover, did not bear any simple relation to those properties of chief interest to users of gelatins. Their experiments were mainly on the factors that affect the gold number determinations and they did not study the properties and characteristics of the gelatin.

Plan of experiment. It is recognized by the authors that the gold number is too technical a test to be carried out by the practical ice cream maker. It was thought, however, that a relation might exist between the gold numbers of the commercial gelatins and one or more of the other tests that are now being used by the ice cream manufacturer. The gold number of the gelatins studied was compared with the hydrogen-ion concentration, ash and moisture content, bacterial count, swelling

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strength, solubility, gel strength and jelly value. A study was made of the effect of each gelatin on the viscosity of the ice cream mix, retention of air by the frozen mixes, standing up qualities or melting resistance of the finished ice cream, and the effect of the gelatins on the flavor and texture of the ice creams after hardening.

Selection of gelatins. Six samples of gelatin were selected for this investigation. In selecting the gelatins an effort was made to obtain one very high grade and one poor grade gelatin. The gelatins were selected on the basis of grade and quality, without any consideration of the brand. In this investigation the gelatins will be referred to by the numbers 1 to 6 inclusive.

Experimental methods. The gold numbers were determined by using the Zsigmondy's (7) red gold sol, prepared by the formaldehyde method. Two methods were used in determining the gold numbers. The one recommended by Elliott and Sheppard (3) (1921) and the other recommended by the Division of Biochemistry of the University of Minnesota. These two methods checked within the range of experimental error. Therefore, only the average results are reported in this paper.

The pH of the gelatins was determined on a Leeds-Northrup Type K potentiometer using a 0.78 per cent gelatin solution. The 0.78 per cent gelatin solution represents the concentration of gelatin in the water phase of an ice cream mix containing 36.5 per cent total solids. The moisture content was determined with the Mojonnier Milk Tester. The ash content was determined by heating 1 to 2 grams of the gelatin in platinum crucibles, at a red heat. The bacterial counts were made by plating a 1:100 solution of the gelatin on plain agar. The swelling strength was determined by adding 5 grams of gelatin to a 100 cc. cylinder and adding enough water at 21°C. to make 100 cc. The gelatin was stirred for one minute to prevent lumping. After the gelatin had soaked for ten minutes the cubic centimeter of swelling was observed. The gelatin was then dissolved by placing the cylinders in a water bath at 60°C. The gelatin was stirred until completely dissolved, and the time in seconds that it took the gelatin to dissolve was used as the rate of solubility.

The gel strength was determined by the Burke Gelatin Standardizer following the method recommended by Burke (1) the originator (1923). The jelly value is represented by the smallest amount that will gel in an aqueous solution. The samples were dissolved and held at 10°C. for thirty minutes before the reading was taken.

The ice cream mixes used in this study were calculated to contain 12 per cent fat, 10 per cent serum solids, 14 per cent sugar, and from 0.3 to 0.5 per cent gelatin. All of these ingredients, with the exception of the gelatin, were mixed together and pasteurized at 63°C. for thirty minutes. The mix was cooled to 110°F. and homogenized at 2000 pounds pressure. The mix was then divided into seven lots. To six of these lots was added one of the gelatins used in this investigation. The seventh lot served as the check mix. Each lot was cooled to 20°C. at which time the samples were taken for viscosity studies, after which the mix was aged 24 hours in the cold room at about 20°C.

The viscosity tests were determined by means of a MacMichael viscosimeter. Standardized wires, standardized in the laboratories of the Dairy Division, were used. The 3 cm. disc bob of the MacMichael was used, and the results reported in MacMichael degrees converted in terms of No. 30 wire.

The ice cream mixes were frozen in a small batch freezer in which it was possible to freeze five different mixes under identical conditions. The time of freezing process varied from twelve to fifteen minutes for different experiments. The temperature of the brine used varied from 11°C. to 12°C.

The retention of air by the ice cream mixes was measured by filling a 100 cc. cylinder with the mix from the freezer. These cylinders were placed in a cold room at 2°C. over night and the next morning they were placed at room temperature and the time noted when the air left the different samples.

To measure the standing up qualities and the melting resistance of the ice creams, pint paper cartons were filled with the mix when frozen and placed in the hardening room at about −18°C. These samples were allowed to harden over night and

the next morning they were placed on a wire gauze over a tall one liter beaker at room temperature (22°C.). Photographs of the ice creams were taken at the end of two and three hours.

Experiment I. Comparison of gold number to H-ion concentration and various common tests used in selecting gelatin for ice cream manufacture. In recent years the ice cream manufacturer has selected gelatin by means of moisture and ash content, bacterial count, solubility, gel strength, and jelly value. The present day manufacturer is giving more attention to gel strength and bacterial count. The object of this experiment was to make a comparison of the gold number of the H-ion concentration and various common tests used in selecting gelatin. The data are presented in table 1.

TABLE 1

Relation of gold number to H-ion concentration and to common tests used in selecting gelatin by the ice cream manufacturer

SAMPLE NUMBER	GOLD NUMBER	pH OF 0.78 PER CENT GELATIN SOLUTION	ASH	MOISTURE	BACTERIA	SWELLING	SOLUBILITY	GEL STRENGTH BURKE METHOD	JELLY VALUE
			per cent	*per cent*	*per gram*	*cc.*	*seconds*		*per cent*
1	0.0048	5.647	1.829	13.27	5,600	33	180	82.0	1.4
2	0.0040	6.002	0.793	10.99	13,500	39	150	82.7	1.8
3	0.017	4.334	0.790	11.08	600	48	165	81.0	2.0
4	0.020	4.809	1.278	11.46	7,300	51	145	74.0	2.2
5	0.013	5.618	2.819	13.85	3,500	47	125	74.3	2.2
6	0.023	3.861	0.964	11.33	300	80	210	84.3	1.8

The smallest gold number represents the highest protective power. Gelatin has been found by all investigators to have the greatest range in gold numbers of any colloid. The range given by Zsigmondy (7) (1917) was from 0.01 to 0.005 and by Gortner (4) (1920) 0.0125 to 0.005. The range found in this experiment was from 0.023 to 0.004. The gold number 0.004 is lower than has been reported by any investigator with gelatin. There was found to be no direct relationship between the gold numbers and any of the other tests used in studying these gelatins.

The gelatin with the lowest gold number had the highest bacterial content and the gelatin with the lowest bacterial content had

the poorest gold number, but the other samples did not follow in order. The ash content seemed to have no direct effect upon the gold number. The swelling strength, with the exception of samples 1 and 2, was very close to an inverse relationship with the gold numbers. The gelatin with the highest strength by the Burke Gelatin Standardizer had the poorest gold number and the sample second highest in strength had the lowest gold number. The gelatin with the highest viscosity had the second best gold number, and the gelatin with the second best viscosity had the poorest gold number. Two of the gelatins had the same jelly value and these two gelatins also had the highest and lowest gold number. With one exception, there was a direct relationship between the gold numbers of these gelatins and the H-ion concentration of the gelatins. Investigators agree that the H-ion concentration affects the gold number determination and this investigation bears out this conclusion.

Thomas (5) (1924) found that if the protective colloid solution is slightly acid it will show a poorer protective action than one which is neutral or slightly alkaline. In this investigation the gelatin with the highest pH had the lowest gold number, and the gelatin with the poorest gold number was found to be the most acid gelatin. Samples 2 and 4 were very close to the isolectric point of gelatin and this may account for the fact that while sample 4 is the more alkaline of the two, yet it has the poorer gold number. While samples 1 and 5 have practically the same pH, sample 5 shows a much poorer gold number which is very likely due to the fact that it is a much lower grade gelatin as is shown by the other tests and characteristics used in examining these gelatins.

Experiment II. Comparison of gel strength. The results obtained in experiment I with the Burke Gelatin Standardizer were carried out according to Burke's method using 5 grams of gelatin made up to 100 cc. In the previous experiment the moisture content of these six gelatins was found to vary from 10.99 to 13.85 per cent. In this experiment the work on gel strength was repeated using a true 5 per cent solution, taking into consideration the moisture content of the gelatins. The

amount of gelatin required to make a true 5 per cent solution, the results obtained on the Burke Gelatin Standardizer, and the amount of each of these gelatins that should be used in the ice cream mix according to Burke's (2) (1923) table for plunger fall are found in table 2.

The gel strengths are uniformly higher in the case of the true 5 per cent gelatin solutions, but the range between the highest and lowest reading is still very narrow. The amount of gelatin to use in the mix is less when the strength is measured using the true 5 per cent solution. However, the range is much narrower than that which was found to be the correct amount to use in the mix of each of these gelatins when a comparison was made of the finished ice creams. In operating the standardizer

TABLE 2

Gel strength by Burke gelatin standardizer

SAMPLE NUMBER	PLUNGER FALL BURKE'S 5 PER CENT SOLUTION	AMOUNT TO USE IN MIX	GELATIN REQUIRED FOR TRUE 5 PER CENT SOLUTION	PLUNGER FALL IN TRUE 5 PER CENT SOLUTION	AMOUNT TO USE IN MIX
		per cent	*grams*		*per cent*
1	82.0	0.39	5.75	91.0	0.345
2	82.7	0.3835	5.61	85.5	0.3725
3	81.0	0.395	5.62	80.0	0.40
4	74.0	0.43	5.65	79.0	0.405
5	74.3	0.4285	5.80	80.5	0.3975
6	84.7	0.3765	5.64	88.5	0.3575

it was found that a difference in 1°C. in the temperature made a difference of several points in the reading, however, it was found with all determinations that the range between the samples was too narrow and moreover there was no simple relationship between the amount of gelatin to use in the mix as shown by the Burke Standardizer and the amount which was found to be the proper amount by experimenting with these gelatins in the ice cream mix.

A STUDY OF GELATINS IN ICE CREAM

Experiments III to V inclusive are devoted to a study of the gelatins in the ice cream mix, and their effect on the resulting

ice creams. It was deemed advisable to study the effect of each gelatin on the viscosity of the mix, the overrun obtainable under the same condition of freezing, the retention of air by the frozen mixes, the standing up qualities or melting resistance of the finished ice cream, and the effect of the gelatins on the flavor and texture of the ice creams after being hardened. A check sample containing no gelatin was compared with the ice cream containing the gelatins in this series of experiments. Sample 7 in this part of the investigation represents the check sample and contains no gelatin.

Experiment III. The effect of various amounts of gelatin on the viscosity of the ice cream mix. The results obtained in experiment II in which the strengths of the gelatins were measured indicated that approximately 0.4 per cent of any of the gelatins with which the investigation was conducted would be sufficient gelatin to use in an ice cream mix. The object of this experiment was to study the effect of varying amounts of the gelatins on the viscosity of the mix. Ice cream mixes were prepared containing 0.5, 0.4, and 0.3 per cent of the gelatins and viscosity determinations were made on the fresh mixes and on the mixes after aging twenty-four hours. The average viscosity reading of three mixes in case of the 0.5 per cent gelatin ice cream, four mixes in case of the 0.4 and 0.3 per cent gelatin creams, and eleven mixes in case of the ice cream containing no gelatin are found in table 3.

TABLE 3

Effect of gelatin on the viscosity of the ice cream mix

SAMPLE NUMBER	VISCOSITY OF 0.5 PER CENT GELATIN MIXES		VISCOSITY OF 0.4 PER CENT GELATIN MIXES		VISCOSITY OF 0.3 PER CENT GELATIN MIXES	
	Fresh	Aged	Fresh	Aged	Fresh	Aged
1	1576.3	4523.6	682.6	1966.5	369.5	764.3
2	1226.7	3531.6	483.5	1401.8	389.7	662.6
3	810.9	2121.2	343.0	748.9	316.3	543.2
4	417.0	839.3	298.0	523.7	301.3	439.0
5	483.0	1035.8	279.5	447.6	373.1	536.5
6	2852.1	Set to gel	1504.5	3336.4	474.5	983.4
7	464.5	677.3	464.5	677.3	464.5	677.3

From the results of this table, and the visible viscosity which could be observed on pouring the mixes, it was apparent to the authors that 0.5 per cent gelatin was too much gelatin to be used in the mix in the case of gelatins 1, 2, 3, and 6. The other two gelatins resulted in an ice cream mix that increased slightly more than the check mix in viscosity on aging. When the amount of gelatin was decreased in the mix to 0.4 per cent it was found that there was a decrease in the viscosity of all the mixes, but this still appeared to be too much gelatin in the case of gelatins 1 and 6, and probably gelatin 2. This proved to be about the correct amount to use in the case of gelatin 3, and the mixes containing gelatins 4 and 5 did not increase as much in viscosity on aging as the check mix. Passing to the 0.3 per cent gelatin mixes it appeared that this amount of gelatin was still a little too much in the case of gelatin 6, and the results indicated that it would probably be better to use a little more than 0.3 per cent of gelatin when using the No. 2 gelatin. While the mixes containing gelatins 3, 4, and 5 increased slightly in viscosity on standing, this increase was less than the check mix. This experiment indicates that gelatin has a marked influence on the viscosity of the ice cream mix and that too much gelatin makes for a plastic mix that is heavy and soggy.

Experiment IV. Retention of air by the mixes. A common fault often found with ice cream is that it 'drops' in the can, or settles. This fault is caused by the air leaving the same, and it was the purpose of this experiment to observe the relative length of time these gelatin ice creams would retain their air at room temperature. In all these experiments the air was always out of the check sample after holding in the cold room (1°C.) over night. In the case of the mixes containing 0.5 per cent gelatin the air completely left samples containing gelatins 3, 4, 5, and check sample 7 at the end of 28 hours at room temperature. The air had just started to leave sample 1 and sample 6 at the end of this period.

In the case of the 0.4 per cent gelatin mixes samples 1 and 6 placed at room temperature had not changed at the end of 5 hours, while samples 4 and 5 had lost nearly all their air at the

end of this period. At the end of twenty-four hours all of the samples except 1 and 6 had completely lost their air, and very little air remained in these samples (nos. 1 and 6) at the end of this period.

In case of the 0.3 per cent gelatin ice creams all of the samples had started to lose their air by the end of five hours.

The range in overrun in the ice cream samples of this experiment was not very wide and could not be given as a reason for the difference in retention of air. In every case the gelatin mixes retained air longer than the check sample and the more viscous mixes retained the air for a longer period. The viscosity of the mix seemed to have a marked influence on the retention of the air in the finished ice cream, the difference in viscosity being due to gelatin.

Experiment V. Standing up qualities or melting resistance of the gelatin ice creams. The melting resistance and the standing up qualities of the ice cream is of considerable importance from the economic side of the ice cream industry. In warm weather a few degrees difference in melting temperature is very important and it was the purpose of this experiment to determine the rate of melting of ice cream containing the various gelatins. Plate I shows the ice creams at the beginning of the experiment, and plates II and III show the 0.5 per cent gelatin ice creams after being held two and three hours, respectively, at 22°C.

At the end of three hours the check sample was nearly completely melted and the part that was left above the wire gauze was mostly foam. Ice cream containing gelatin 6 did not melt but a small amount of a light yellow liquid had come out of the mix at the end of three hours. This liquid was very sweet and did not have the characteristic ice cream taste of the liquid from the check sample. The reason why this sample did not melt may have been due to its power to imbibe large quantities of water and thus hold the water in the ice cream mix. The liquids from samples 4 and 5 had the ice cream taste but they were slower in melting than the check sample. The other four samples all became soft, and all but sample 6 spread out on the wire guaze. These mixes were leathery and gummy.

The standing up qualities of the 0.4 per cent gelatin ice creams are shown in plates IV and V. It will be noted that the check sample appears quite similar to the check sample shown in plates II and III which illustrate the 0.5 per cent gelatin ice creams, but samples 4 and 5 in the experiment melted down without leaving any foam on top of the wire gauze. Sample 6 did not melt but did break earlier and spread out more. Samples 1, 2, and 3 melted slightly, but most of the mix spread out and ran off the side of the wire gauze.

The results of the 0.3 per cent gelatin mixes are shown in plates VI and VII. Here it will be noted that samples 1, 2, 4, and 5 had completely melted at the end of three hours, and also that these mixes had melted through the wire gauze. Sample 3 was also nearly all melted but some of this sample ran over the side of the gauze. Sample 6 still refused to melt like the other samples of ice cream at this concentration of gelatin. While sample 6 did not melt at any concentration of gelatin used in this investigation, it was not an ice cream that would take with the public. It was a heavy, soggy, and leathery ice cream that was hard to dip and left an after-taste in the mouth after eating. The same relationship existed between the standing up qualities of these gelatin ice creams and viscosity as there was between the retention of air and the viscosity. The more desirable ice cream was the one that melted down smooth and the liquid had the characteristic ice cream taste.

DISCUSSION

The practical ice cream manufacturer is interested in the grade of the gelatin and the amount of the gelatin he must use in his mix to obtain the results which he desires. In the experiments with the use of these gelatins in the ice cream mix special attention was given to this point and a study of the effect of the gelatins on the finished ice cream indicated that the proper percentage of each of these six gelatins to use in the mix to make a desirable commercial ice cream was as follows: Gelatin 1—0.3 per cent, Gelatin 2—slightly more than 0.3 per cent, Gelatin 3—0.4 per cent, Gelatin 4 and Gelatin 5—0.5 per cent, and Gelatin 6—less

than 0.3 per cent. If the ice cream manufacturer assumes that 0.5 per cent is the correct percentage of gelatin to use of all lots of gelatin which he buys, he is sure to have trouble as the results of this investigation show that this percentage of some grades of gelatin results in an ice cream that is heavy, soggy, gummy, leathery, and gives the ice cream an undesirable after-taste. The use of a high grade gelatin is not to be discouraged because the same results can be obtained by using a smaller percentage of such gelatin and a very desirable ice cream can be made with it by using the proper percentage. However, it is much more important that the proper percentage be used with the high grade gelatin because of the marked effect of this gelatin on viscosity of the mix, melting resistance, body, texture, and flavor of the finished ice cream.

CONCLUSIONS

1. No direct relation exists between the gold number of gelatin and the common tests used by the ice cream manufacturer in selecting gelatin with the possible exception of the swelling test.

2. There was no direct relation between gel strength, as measured in this paper, and the amount of gelatin to use in ice cream.

3. Gelatin has a marked influence on the viscosity of the ice cream mix but too much gelatin results in a plastic mix which is heavy and soggy.

4. Ice cream containing gelatin will retain air much longer than ice cream containing no gelatin, this property, however, varies with the amount and grade of gelatin used in the mix.

5. The following tests should be used by the ice cream manufacturer in selecting gelatin for use in ice cream:

(1) Bacterial count.
(2) Ash content.
(3) Moisture content.
(4) Swelling test.
(5) The effect of the gelatin on the standing up property of ice cream at room temperature.

6. Until further contributions are made to the subject, the most practical method of judging gelatin for ice cream manufacture is that of actually testing the gelatin in ice cream and noting the effect on the standing up properties of the ice creams at room temperature.

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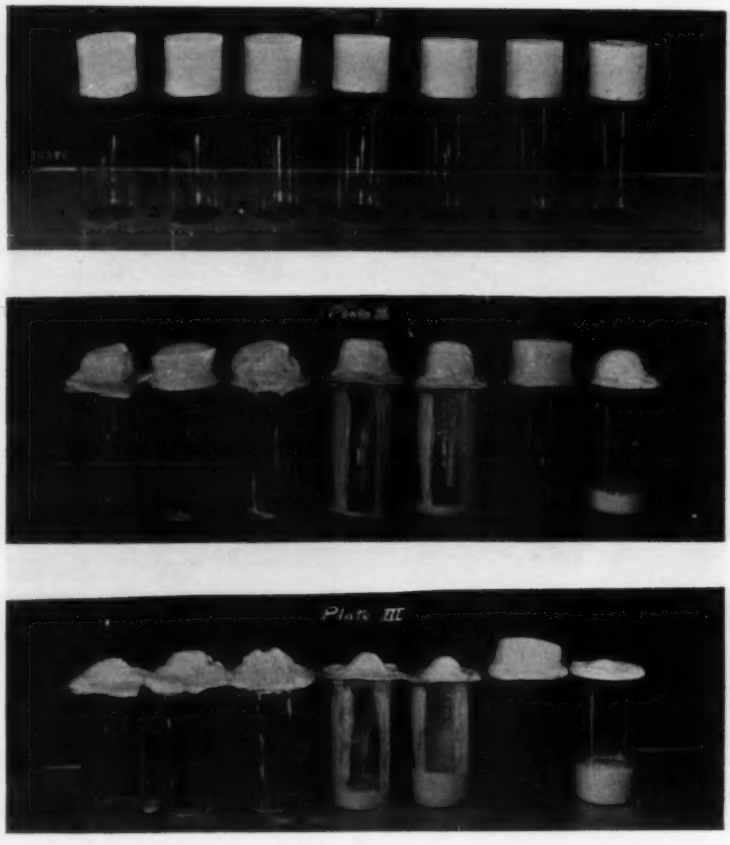
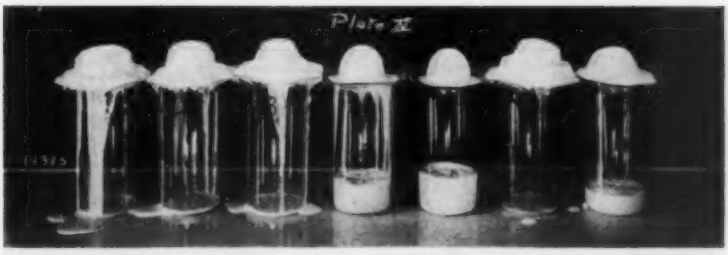


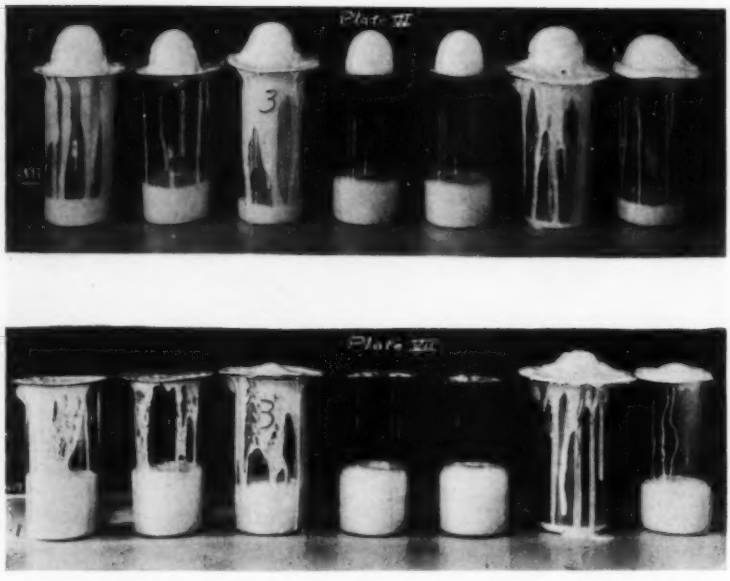
ICE CREAMS CONTAINING 0.5 PER CENT OF THE GELATINS STUDIED

Plate I illustrates the ice creams at the beginning of the experiment, plates II and III the ice creams after standing at room temperature two and three hours respectively. Samples 1 to 6 inclusive contain the gelatins under study, sample 7 is the check containing no gelatin.



ICE CREAMS CONTAINING 0.4 PER CENT OF THE GELATINS AFTER SETTING AT ROOM TEMPERATURE TWO AND THREE HOURS RESPECTIVELY

Samples 1 to 6 inclusive contain the gelatins under study, sample 7 is the check containing no gelatin.



ICE CREAMS CONTAINING 0.3 PER CENT GELATIN PLACED AT ROOM TEMPERATURE FOR TWO AND THREE HOURS

Samples 1 to 6 inclusive contain the gelatins under study, sample 7 is the check containing no gelatin.

THE EFFECT OF HOMOGENIZATION, CONDENSATION AND VARIATIONS IN THE FAT CONTENT OF A MILK UPON THE KEEPING QUALITY OF ITS MILK POWDER*

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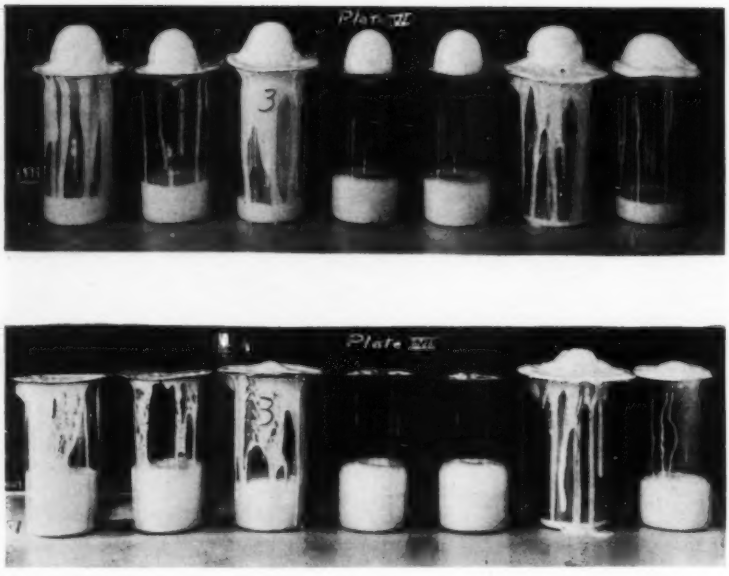
There is considerable difference of opinion with respect to the relative keeping quality of milk powders manufactured by different processes. Coutts (1), also Palmer and Dahle (2), have noted that the drum process produced powders superior in keeping quality to powders manufactured by the spray processes. Palmer and Dahle have attempted to explain these results on the basis of the physical structure of the powders, showing that in a spray powder air is occluded in the milk particles and therefore the fat in this powder is subjected to the action of oxygen from within as well as upon the outer surface. These authors also suggest that homogenized fat in a powder produces a condition favorable for accelerated oxidizing action of air due to the increase surface area.

The present writers (3), though having no experiments to prove that drum powders had a better keeping quality than spray powders, accepted the observations made by the above mentioned authors, but maintained also that the quality of the fat largely determined the keeping quality of the powder manufactured.

Later experiments by Dahle and Palmer (4) do not fully substantiate their former conclusions. They maintain that a spray powder, which contains its fat in a finer state of division, and therefore exposes the greatest surface to the action of air, seems to possess the best keeping quality in this case. They also intimate that a spray powder owes its superior keeping quality to closer packing because of its fineness, and also to the smaller air cells occluded within the granules. The lack of the latter condition

* Received for publication June 25, 1925.



ICE CREAMS CONTAINING 0.3 PER CENT GELATIN PLACED AT ROOM TEMPERATURE FOR TWO AND THREE HOURS

Samples 1 to 6 inclusive contain the gelatins under study, sample 7 is the check containing no gelatin.

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hardly accounts for the inferior keeping quality noted by these authors for the drum powder.

If comparisons of methods of manufacture or comparisons of products produced by different processes are to be made, it is obvious that it would be ideal if samples of the same milk could be used throughout. Where the history of the milks, i.e., age, cooling, heat treatment, fat content, mechanical treatment, etc., are identical, comparisons are justified provided the method of judging the product takes into consideration the initial stability or susceptibility of the powder to oxidation in each case.

It is also essential in comparing powders, that the moisture content (better vapor pressure of the powders) be as nearly equivalent as possible, and that they be thus maintained throughout the tests. The variability in moisture content is of especial importance where deterioration (oxidation) is judged by the olfactory sense, since it has been shown (5, 6) that free moisture has a decided effect upon the stability of the compounds responsible for the tallowy odors and flavors. A relatively dry sample is apt to show deterioration in shorter time than a sample of higher moisture content, when in fact the rate of deterioration (oxidation) may be the same.

Any experiments, therefore, where the above mentioned conditions are not carefully controlled are subject to irregular and erroneous results and sometimes erroneous conclusions.

The aim of this investigation was to determine the value of some basic methods of procedure, involved in the processes of milk powder manufacture, in improving the keeping quality of the product. The effect of condensation, homogenization or its equivalent in the process of drying and the variations in fat content of milks, upon powder produced will be discussed in this paper.

EXPERIMENTAL

The effect of acid content of a fat upon its resistance to oxidation has been recorded in a former publication (7). It has also been noted that an aged sample of milk always produces a butter oil of lowered resistance to oxidation. For these reasons samples

of milk more than twelve hours old were never used in the following experiments. Fresh samples of milk that had been properly cooled were standardized to the fat content required, heated to 60° to 65°C. for approximately one-half hour, and reduced to powdered form by the spray method. Approximately the same

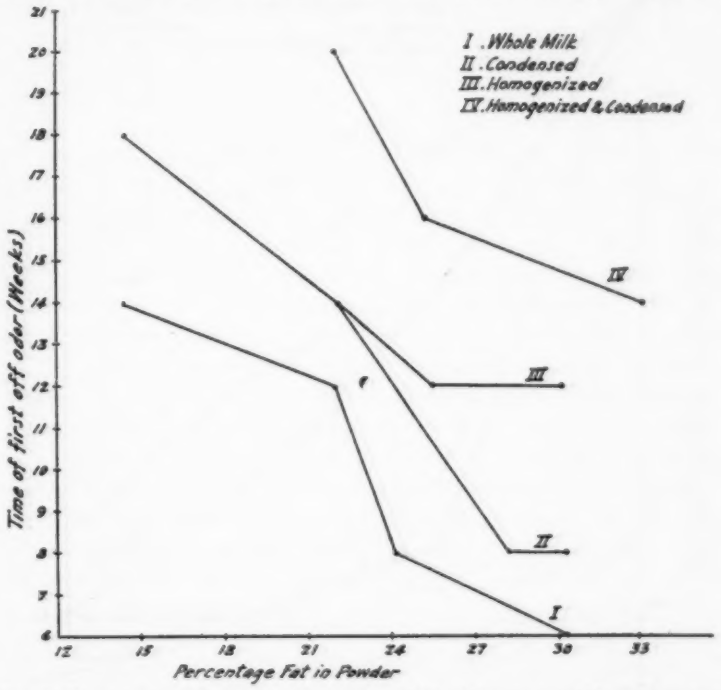

FIG. 1. SHOWING THE EFFECT OF VARIATION IN FAT CONTENT OF MILK POWDERS MANUFACTURED FROM WHOLE, CONDENSED, HOMOGENIZED, AND HOMOGENIZED AND CONDENSED MILKS UPON THEIR KEEPING QUALITY

moisture content was maintained. The various powders were sealed in small tin cans and stored at room temperature. From time to time a can from each sample was opened and tested. The time when tallowiness first appeared, as judged by several individuals, was noted. These results are plotted in figure 1.

In view of the fact that the olfactory sense does not give an

entirely satisfactory measure of the actual condition or state of the fat in the powder, and gives no measure of susceptibility changes to oxidation which takes place in the fat with aging, the experiments were repeated in part.

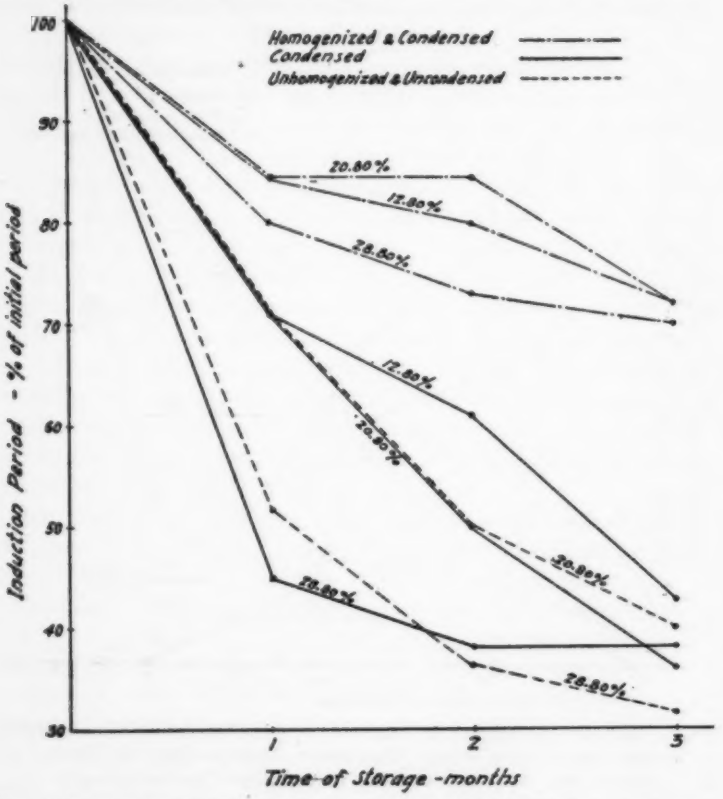

FIG. 2. SHOWING THE EFFECT OF VARIATION OF FAT CONTENT, HOMOGENIZATION, CONDENSATION, AND HOMOGENIZATION AND CONDENSATION OF A MILK UPON THE RESISTANCE OF THE FAT IN ITS POWDER TO OXIDATION

Samples were prepared and stored as described above. From time to time, the induction period, or the time necessary to cause the fat in the milk powder to absorb oxygen at 70°C., was deter-

mined by the method described by Greenbank and Holm (8). By this method it was possible to follow directly the susceptibility changes in the fat, upon storage. The initial induction period, or time necessary for oxygen absorption to begin, was determined

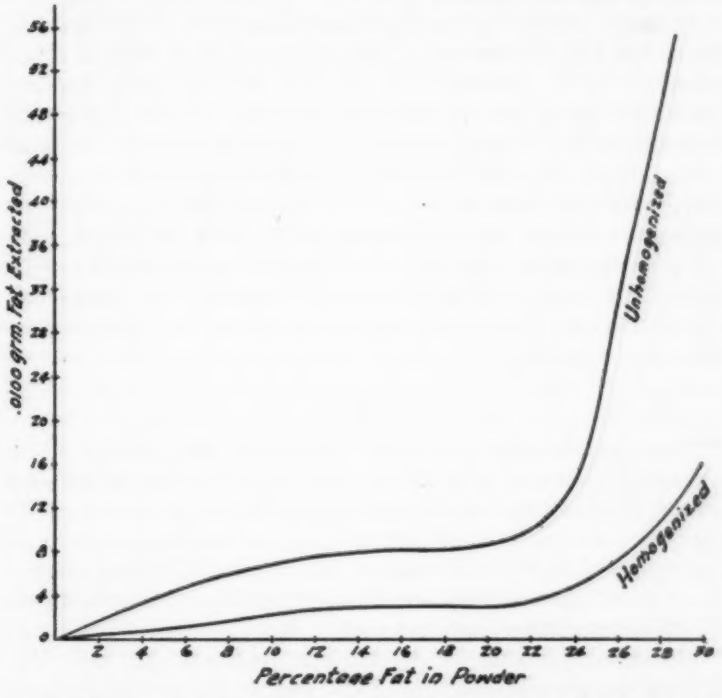

FIG. 3. SHOWING THE AMOUNTS OF FREE FAT EXTRACTED FROM MILK POWDERS OF VARYING FAT CONTENT MANUFACTURED FROM HOMOGENIZED AND UNHOMOGENIZED MILKS

upon each sample, thus correcting as far as possible any variation in powders manufactured from different milks. The results are plotted in figure 2.

The results of these two sets of experiments seem to indicate that there is quite a perceptible decrease in keeping quality with increased fat content, especially within the higher ranges. The

quality of the powder seems also to be materially improved by condensation in the first set of experiments (fig. 1). These results are not so pronounced in the confirmatory experiments (fig. 2). The beneficial effect of homogenization is well illustrated in figures 1 and 2.

In some preliminary experiments it has been noted that the amount of free fat (fat not protected by a protein film) as determined by a CCl_4 extraction, would vary with different powders, especially in powders of higher fat content. It was decided to determine if the increase in free fat in the stored samples and their susceptibility to oxidation bore any direct relationship. Milk powders of from 20 to 30 per cent fat content manufactured from homogenized and unhomogenized milks were extracted with CCl_4. Varying the time of extraction and the amount of sample used showed very little effect upon the per cent of fat extracted. The results showing the variation in free fat in these powders are plotted in figure 3.

DISCUSSION

The comparison shown in figure 1 seems to indicate that a precondensed sample of milk will produce a powder of better keeping quality than will the unprecondensed. This is in accord with the experiments carried out by the authors upon pure butter oil. In every case where a pure butter oil was treated in such a manner that some of the volatile or water soluble products were removed, the keeping quality was improved.

The extent to which different heat treatments of the milk affected the keeping qualities of its powders has not been ascertained. It is reasonable to assume, however, that any increase in heat treatment will improve the keeping quality of a powder, since the tendency of heat treatment, when applied to a reasonably fresh product, is to remove the volatile substances or in some way remove the substances which act as catalysts for the oxidation.

Homogenization seems to have a decided effect in improving the keeping quality. This is strikingly brought out in the second series of experiments, where resistance to oxidation was measured

directly by the ability of the fat in the powder to withstand oxygen absorption. The mechanism of prevention of oxidation in this case is not clear.

The suggestion first made by Palmer and Dahle that the fat in a spray powder oxidizes more rapidly than does the fat in a drum powder, and that the oxidizing action is induced by a greater surface exposure due to greater subdivisions of fat globules, seems to be strongly contradicted.

Whether the protective action against oxidation given by homogenization is largely physical in nature or both physical and chemical, still remains an open question.

The antithesis of the above idea, namely, that presence of free fat in a powder should increase susceptibility, appears perhaps to furnish an index to susceptibility, other conditions being equal.

A correlation of figures 1 and 3 indicates that the breaks in the curves obtained for the keeping quality, and those obtained for free fat extracted, occur at approximately the same per cent fat content. No extracts were made upon the samples used in the second set of experiments. Though definite proof is lacking as to the exact nature of the retarding action, the results indicate that the limited covering power of a milk for the butterfat has much to do with the keeping quality of the milk powder manufactured from this milk.

It has been reported by Supplee (9) that increases in fat content from 5 per cent to 55 per cent showed progressive improvement in keeping quality. These results are in direct contradiction to the results obtained by the writers for powders of fat contents up to 33 per cent. The author does not state, however, how the fat content of the milk was increased.

Powdered cream presents an entirely new problem, in which the intensity factor of the various conditions must be considered even more carefully. Direct comparison between the fat in this product and that in whole-milk powder must be made with even more care than when whole-milk powders are compared.

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THE ENERGY REQUIREMENTS OF DAIRY COWS*

II. IS NET ENERGY OR METABOLIZABLE ENERGY THE MORE USEFUL INDEX FOR PRACTICAL PURPOSES?

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INTRODUCTION

In the previous article of this series (9) it was shown that the experimental results obtained at the dairy experiment farm of the United States Department of Agriculture, at Beltsville, Md., are in close agreement with those of Haecker and Eckles in regard to the quantities of total digestible nutrients which are necessary to keep dairy cows at uniform body weight. It was shown also that the experiments of Eckles, on the one hand, and of this station on the other, which are in close agreement in regard to the quantities of total digestible nutrients necessary to maintain uniform body weight, are in less close agreement when their results are calculated in terms of net energy values; and, further, that this situation is readily explained by supposing that net energy values are a less accurate measure of the relative values of different feeds for maintaining uniform body weight than are total digestible nutrients. It is proposed in this article to inquire into the physiological justification for using either total digestible nutrients or net energy values as a measure of the practical value of feeds.

An admirable discussion of the distribution of energy in foodstuffs from the physiological point of view is given by Armsby (5, pp. 635–678). It will not be necessary to repeat it here. It need only be said that the terms developed by him will be used in this discussion in the sense in which he defined them. The gross energy of a food, according to Armsby, is the maximum amount of energy which it can furnish for the vital activities by its oxida-

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tion in the body, and is measured by its heat of combustion (5, p. 635). The metabolizable energy is the difference between the chemical energy of the feed and that lost in the excreta, or is that portion of the energy of the feed which is capable of being converted into other forms of energy in the body, either during the changes which the feed undergoes in the digestive tract or in the course of metabolism in the tissues (5, pp. 639, 640). Net energy is that portion of the energy of the feed which remains after deducting the losses of energy in the excreta and those due to the increased heat production which results from the consumption of the feed (5, p. 659).

What is meant by the total digestible nutrients of a feed is so well known as to need no recapitulation here. But it is worth while to point out that the figures for total digestible nutrients as given in the text book of Henry and Morrison (7, pp. 653–666), are intended to be a measure of the metabolizable energy of the feeds concerned, and that it is for this reason that the weight of digestible fat in the feeds is multiplied by the factor 2.25 in calculating the total digestible nutrients (see Henry and Morrison, (7, pp. 39–41)).

The meaning of the term "net energy value" and the experimental method by which net energy values have been determined may be further elucidated as follows. It has been found that when food is given to a partially or completely starving animal, not all of its metabolizable energy is used to replace that of the body tissue which the animal was previously burning up. The result usually is that while the waste of the animal's body tissue is lessened, its total heat output is, at the same time, increased. In other words, only a part of the energy of the food given is used to prevent waste of body tissue; the rest is converted into heat. In Armsby's experiments the heat output of animals is determined, first during a period in which they are fed a markedly submaintenance ration, and then during a period in which they are fed a larger though still somewhat submaintenance ration of the same food material. From the data so obtained that portion of the energy of the extra food given in the second period which is turned into heat and that part which is used to save body tissue

are calculated. The latter portion is called the net energy value of the food (5, p. 271).

In other cases the net energy values of foods for fattening animals have been determined. In such experiments additional food is given to an animal which is already on a maintenance or super-maintenance ration, and it is determined what proportion of the metabolizable energy of the added food is stored by the animal as body fat or other body substance and what proportion is lost as heat. That portion of the metabolizable energy of the food which is stored as body fat or other body substance is called the net energy value of the food for fattening or growth (5, p. 360).

It is proposed in this article, first to point out that the results of past experiments have been such as to indicate that it will be very difficult to obtain satisfactory average figures for the net energy values of foods, even for the very special conditions which have obtained in the calorimetric experiments. In a later section, it will be inquired whether any figures which could be obtained in such experiments are likely to have a greater value for indicating the relative usefulness of foods in practice than are figures for the metabolizable energy values of the foods in question.

THE VARIABILITY OF THE FIGURES OBTAINED IN PAST CALORIMETRIC EXPERIMENTS

The writer has made a particularly detailed study of Armsby's work. It is to be noted, however, that the same fundamental idea underlies the work of Armsby and that of Kellner; and the same criticisms, therefore, apply in a general way to both. The following discussion is confined chiefly to Armsby's work merely for purposes of clearness and definiteness. The writer also wishes it to be understood that he has the most sincere admiration for the care and accuracy with which Armsby's experiments were carried out and for the clearness with which very difficult and complicated matters have been set forth in the published accounts of them; he fully realizes that Armsby and Kellner and their collaborators have achieved scientific advances of great permanent value. But he is none the less convinced that the limitations of the net energy conception should be fully realized by every one

who is interested in the science of nutrition and the practical feeding of farm animals.

The conceptions, net energy value and starch value,[1] distinguish between that part of the energy of a food which is used to maintain or increase body substance and that part which is turned into heat. Net energy values and starch values are determined by measuring and comparing the heat output of animals in two separate periods in which they receive different amounts of food.

Now the heat output of an animal depends very largely on its muscular activity, and the extent to which a living animal uses its muscles in any given period depends on many other factors besides the food which it receives during that period. The results of an experiment to determine the net energy value of a food would be vitiated if, for example, it happened that the experimental animal were successfully protected from flies in one of the periods, but that flies gained access to it in the other period. The muscular activity and consequently increased heat output occasioned by the flies in one of the periods would introduce a very large error. Similarly, if the temperature were much lower in one of the periods than in the other, the animal might be caused to shiver; and this also would introduce a very large error.

In order to avoid errors of the kinds referred to, it is necessary to keep the animals used in this type of experiment under uniform conditions. Armsby and Fries give a striking description of the precautions which they used. There were no external noises except the monotonous click of the meter pump, no visitors were admitted, the temperature in the calorimeter was kept at from 17° to 18°C., even the change from daylight to artificial light was hardly perceptible, and the animals were all docile and accustomed to the experimental conditions (4, pp. 464–475).

A careful study of the experimental results, however, shows that in spite of these precautions the muscular activity of the animals was affected by uncontrollable influences as well as by the nature and amount of the food given. It was found, for instance, that the animals gave off about 40 per cent more heat

[1] For a discussion of the meaning of "starch value," see Armsby (5).

when standing than when lying down (3, p. 23), that the proportion of time spent standing varied from 24 per cent to 100 per cent of the whole period spent in the calorimeter and was, to a large extent, independent of the food consumed (4, p. 460–462).

It is not an easy matter to decide how to deal with this difficulty. It is obvious, of course, that an animal may be induced to spend a large proportion of its time standing by uncontrollable influences other than the food which it receives, and that large errors will be introduced into the determinations of net energy, if the standing due to these chance extraneous influences is counted as due to the influence of the food. On the other hand, there is no doubt that an increased food supply has a general tendency to cause increased muscular activity in animals, and this tendency appears quite clearly in the results of Armsby's experiments. It was found, for instance, that the animals which received more food had a decidedly greater tendency to change often from the standing to the lying position, though only a slight tendency to spend a larger proportion of their time standing (4, p. 460). In order to obtain really accurate results, therefore, the investigation would have to distinguish between the muscular activity due to accidental extraneous influences and that due to increased food intake.

Armsby and Fries apparently changed their opinion in regard to the question whether the changes in heat output due to standing and lying down should be counted as due to changes in food intake or regarded as accidental. In Bulletin 51 of the Bureau of Animal Industry (1) they take this factor into account in drawing conclusions from their results. In Bulletin 74 of the same series (2), on the other hand, they calculate the net energy values of the foods used without considering what proportion of the time the animals spent standing or lying in the various periods of the experiments. In Bulletin 101 of the same series (3) and in later articles, they return to the practice of taking into account the proportion of time spent standing.

Whichever way the results are calculated, they vary widely in different individual experiments. In Bulletin 74 of the Bureau of Animal Industry, for instance, the results, calculated without

regard to the proportion of time which the experimental animal spent standing or lying in the different periods, lead to the conclusion (2, p. 40) that the net energy of clover hay amounts to 36.42 per cent of its metabolizable energy. In Bulletin 101, the authors correct the results to the supposition that the experimental animal spent 17 hours standing and 7 hours lying down each day. From the figures given on pages 32 to 35 (3), however, it is possible to calculate the results on the same basis as in Bulletin 74 (2); when this is done, it appears that in the two most satisfactory experiments,[2] the net energy of the clover hay was about 85 and 64 per cent of its metabolizable energy respectively. Correcting the results to the supposition that the ox spent seven hours of each twenty-four lying down, the authors find in three different cases that the net energy of the hay was 79.99, 72.90, and 92.74 per cent of the metabolizable energy respectively (see 3, p. 40).

Further data on the distribution of nutritive energy in clover hay are given in a still later article (4, p. 473). In this case, the increments in heat production caused by clover hay per kilogram of dry matter are given, the results being corrected to the supposition that the experimental animals spent half their time lying down. It appears that in one case the hay caused the heat output to be increased at the rate of 992 calories per kilogram of dry matter fed; in another case, at the rate of 453 calories per kilogram. In order to compare these results with those given above, it is necessary to know the metabolizable energy of clover hay. This quantity is comparatively constant; in figures given on page 34 of Bulletin 74 and on page 32 of Bulletin 101 the utmost variation is from 2.290 to 2.024 calories per gram of total organic matter in the hay, and the average may be taken as approximately 2040 calories per kilogram of total dry matter.[3] Using this figure for metabolizable energy, the figures given above would

[2] Some of the experiments described in this bulletin are vitiated by the fact that the ox, for unknown reasons, stood up during the whole 48 hours of one of the periods.

[3] About 6 per cent of the total dry matter of clover hay is ash, and therefore the metabolizable energy per kilogram of total dry matter is somewhat lower than the energy per kilogram of total organic matter.

mean that in one experiment the net energy was 51 per cent of the metabolizable energy; in the other, 78 per cent. These figures are to be compared with those of Bulletin 101, in which the authors calculate that the net energy of clover hay is from 72.90 to 92.74 per cent of the metabolizable energy.

The figures given by Armsby and Fries for the net energy of clover hay are perhaps somewhat more variable than those given for other foods. But the other figures are also highly variable. On page 473 of the article in the Journal of Agricultural Research above cited, for instance, are given figures for the increments in heat production per kilogram of dry matter caused by timothy hay. These range from 529 calories to 954 calories. It is a very moderate statement, therefore, to say that the net energy of any given feed may often turn out to be 50 per cent more in one experiment than it is in another, even when the results are calculated with all the refinements and precautions described by Armsby and Fries in the article just cited.

This variability in the results is not in the least surprising; on the contrary, it is entirely to be expected. The reasons for it have already been outlined and may be restated as follows: The heat output of an animal, under such conditions as those that obtain in the experiments of Armsby and Fries, is largely dependent on the degree of its muscular activity, and the muscular activity is influenced, not only by the food intake, but also by other accidental factors which it is impossible to control. When Armsby and Fries correct for the proportion of time which their animals spend standing, they tacitly admit that one form of muscular activity may be accidentally increased in such a way as to interfere with the value of the results. But the muscular activity involved in standing is only one form; another is that involved in frequent changes from the lying to the standing position; still another expresses itself in increased restlessness either while standing or while lying down. Armsby and Fries make no attempt to correct for these other forms of muscular activity; and, as a matter of fact, it is impossible to correct satisfactorily either for them or for the muscular activity involved in standing. For there is every reason to believe that increased food intake

stimulates to increased muscular activity, and whatever part of the muscular activity is so caused must be taken into account as a part of the effect of the food. But, in order to get ideal results, this part of the muscular activity would have to be distinguished from the part which was accidental, and to make this distinction is impossible in such experiments as those under consideration.

The writer has made a careful study of the experimental basis for some of the net energy values published in Armsby's book (5, pp. 715–721) and has compared these figures with figures given by Kellner (8, pp. 627–639) for the starch values of the same foods. The experimental results on which the figures given in the book rest are quite variable and not very numerous, and the net energy values do not run at all parallel to the starch values for the same foods. It is, however, not necessary to go into this question in detail, as it is generally realized that the determinations of net energy value were incomplete at the time of Dr. Armsby's death. In a recent note (6), his successor has stated that all the figures for net energy values which have been published from the Institute of Animal Nutrition of the Pennsylvania State College are to be recomputed and corrected, and that Dr. Armsby himself regarded the published results as tentative.

WOULD IDEAL FIGURES FOR NET ENERGY AS DETERMINED IN ARMSBY'S EXPERIMENTS BE A BETTER INDICATION OF THE RELATIVE VALUES OF DIFFERENT FOODS UNDER PRACTICAL CONDITIONS THAN WOULD FIGURES FOR THEIR METABOLIZABLE ENERGY?

The experiments of Armsby and Fries, on which many of the figures for the net energy values of foods given in Armsby's book are based, were carried out under very special conditions. The animals were kept as quiet as possible in a calorimeter at a temperature of 17° to 18°C. It is legitimate to inquire whether the relative tendencies of different foods to stimulate the output of animal heat would run parallel under such conditions to their tendencies to stimulate heat output under the quite different conditions which obtain in practice.

It was the old idea that a considerable amount of energy was necessary for the mastication, digestion, and assimilation of foods,

particularly of roughages; and that the heat output caused by the consumption of food in such experiments as those of Armsby and Kellner was a measure of this energy. If this idea were correct, the net energy and starch values would probably be the best possible indication of the practical usefulness of the nutritive energy contained in different foods; for it would be entirely logical to believe that the mastication, digestion, and assimilation of a given quantity of any particular food would always require about the same amount of energy, whether the animal were resting or active, and whatever the external temperature might be.

But Armsby and Fries make it quite clear that the heat output of the animals in their experiments which was caused by the consumption of food was not entirely or even chiefly a measure of the energy which was required for mastication, digestion, and assimilation. The reasons for discarding this older view are very fully and clearly given in their article in the Journal of Agricultural Research (4). On page 459 of that article, for instance, it is stated that there was frequently no increase in heat output by the animals while they were masticating their food; and rather frequently, a distinct fall. This interesting observation may be interpreted in various ways; a not improbable interpretation is that the effect of mastication was to reduce other muscular movements, so that the loss of energy through this process was compensated or overcompensated, and may be regarded as often not occurring at all from a practical point of view. But, however the observation is interpreted, it shows clearly that the increased heat output due to mastication is either zero or at most a small fraction of the total nutritive energy of the food.

On page 460 the authors give reasons for thinking that their animals were more restless on the heavier rations, and on page 479 they state that from 3 to as much as 30 or 40 per cent of the increased heat output caused by the consumption of food appears to have been due to increased muscular activity while standing. On page 477 they show that coarse woody feeds cause less increase in heat output per kilogram dry matter consumed than do concentrates. On page 479 they speak of the stimulating action which food has on general metabolism in addition to its effect in

stimulating muscular activity, and express the opinion that this factor is not inconsiderable.

From the above cited passages it is fair to conclude that Armsby and Fries are strongly of the opinion that the increased heat output caused in animals by the consumption of food is, to a large extent, due to the stimulating action which food has on muscular activity and on general metabolism, and to a small extent only, to the work required for mastication, digestion, and assimilation. With this conclusion the present writer is in entire agreement. But, if this conclusion is correct, a large part of the basis for believing that the net energy and starch values of foods as determined in Armsby's and Kellner's experiments are a good indication of their practical usefulness for maintenance and fattening, is lost.

It is natural to suppose, as stated above, that the energy required for the mastication, digestion, and assimilation of a given quantity of any particular food would be the same, whether it were fed by itself or along with other foods, whether the animal which consumed it were active or resting, and whatever the external temperature might be. But it is by no means equally clear that the relative tendencies of different foods to stimulate muscular activity and increased general metabolism would remain uniform under all these different conditions. Unless this point is established, the figures for net energy values obtained in calorimetric experiments cannot be regarded as necessarily valid for practical conditions.

In the preceding paper of this series (9) evidence was presented which indicates that the figures for total digestible nutrients given in the tables of Henry and Morrison are a reasonably satisfactory measure of the relative values of foods for maintaining uniform body weight in dairy cows. These figures aim at giving the metabolizable energy of foods. But they are not an exact measure of metabolizable energy. The relation between the total digestible nutrients and the metabolizable energy of foods is clearly discussed by Armsby; he recognizes that the former is an approximate measure of the latter, and gives figures from which an idea may be formed as to how far the two sets of values may

depart from strict parallelism (5, pp. 635–650). The reasons for the non-existence of strict parallelism are, in brief, that certain metabolic products, particularly methane, have not been taken account of in determining the coefficients of digestibility of the various farm foods. Armsby gives methods by which metabolizable energy may be calculated from the figures for the digestible nutrients (5, p. 650).

In order to obtain the therms of metabolizable energy in a pound of roughage, the total digestible organic matter[4] therein contained is multiplied by 1.588; the corresponding factor for grains and similar material with less than 5 per cent digestible fat is 1.769; for grains with more than 5 per cent fat, 1.814; for oil meals and materials high in protein, 2.086. The figure 2.086 is about 31 per cent higher than 1.588. This means that the extreme error that could be made by taking the total digestible organic matter of foods as a measure of their metabolizable energy would be 31 per cent.[5] Such an error, however, would be made only in cases where one set of animals was fed entirely on roughage; and the other set entirely on oil meals and materials high in protein. As a combination of roughage and concentrates is fed under almost all practical and experimental conditions, the error under consideration would be much smaller than this in most cases, and would probably seldom rise above 10 per cent.

It may be concluded, therefore, that experimental results which indicate that the total digestible nutrients are a good index of the practical value of foods as sources of nutritive energy, indicate also that metabolizable energy is a good index in the same sense. The experimental evidence obtained from dairy cows and bearing on this question has already been discussed (9). The remarkable agreement between the results of Haecker and Eckles and those obtained at the Beltsville farm in regard to the quantities of total

[4] The total digestible organic matter contained in a food is the same as the total digestible nutrients, except that in the former case the actual weight of the fat is added to that of the other constituents, instead of the weight of the fat multiplied by 2.25.

[5] The error would obviously be somewhat less in most cases if the total digestible nutrients were taken instead of the total digestible organic matter, as the high nutritive energy of fat is allowed for in computing the former figures.

digestible nutrients necessary to maintain dairy cows at uniform body weight indicates that either total digestible nutrients or metabolizable energy would constitute a better index of the practical value of feeds as sources of nutritive energy for this class of farm animals than any other that exists at the present time.

From the existing information the point should be emphasized, however, that no system of measuring the nutritive energy of foods will give more than very limited information regarding their relative practical values in a general sense. Even for animals that are simply being maintained at uniform body weight or fattened, certain definite chemical compounds must be supplied in the food; and, in the case of animals which are growing or producing milk, eggs, or wool, the problem of chemical requirements rather overshadows that of the energy requirements. Unless the chemical requirements are adequately met, the most exact system of determining the nutritive energy of different foods will be useless.

SUMMARY

The net energy or starch value of a food is that fraction of its metabolizable energy which an animal can use for maintenance or fattening. But the value of this fraction in any particular instance depends on the heat output of the animal in question, and this again depends on the degree of muscular activity, and on the external temperature. Net energy and starch values will not, therefore, be constant for any given food unless they are determined under fixed conditions. As the fixed conditions for their experiments, Armsby and Fries have chosen an external temperature of about 17°C. and the least possible stimulation to muscular activity.

A careful study of their results shows that even under the most uniform conditions which they were able to obtain, the muscular activity of their animals was unevenly influenced by uncontrollable accidental causes, so that the results of individual experiments on the same food were highly variable. It is questionable whether their experiments were sufficiently extended to establish

reliable approximate averages even for the conditions above described.

That values obtained under these conditions would not be applicable under all practical conditions is obvious. In Armsby's system energy converted into fat is regarded as net, and energy transformed into muscular activity is counted as waste; for draft animals the reverse is the case.

It is probable that net energy values obtained under the conditions of Armsby's experiments would be more or less inapplicable under almost all practical conditions. In order to suppose that they would be applicable, one must make a number of questionable assumptions, among which the most important are that the relative tendencies of different foods to stimulate useless muscular activity and other useless forms of heat output would remain constant, whether these foods were fed by themselves or along with others, and to whatever conditions of rest and activity or of external temperature the animals concerned were subjected.

Experiments carried out on dairy cows indicate that the existing figures for the total digestible nutrients of dairy feeds furnish a very good measure of the relative values of these feeds as sources of nutritive energy under practical conditions. As the figures for total digestible nutrients are the nearest existing approach to the measure of the metabolizable energy contained in feeds, it may be supposed that figures for metabolizable energy would also furnish a good system for measuring feeds as sources of nutritive energy under practical conditions.

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DAIRY NOTES

THE EFFECT OF INJURY ON THE COMPOSITION OF COW'S MILK

A registered Ayrshire cow in the University of Illinois herd became ruptured, leaving a swelling about 6 to 8 inches in diameter, a little in front and to the right of the udder. It was thought worth while to obtain a sample of milk from her to see if the injury might influence its composition. Analyses of samples taken from her earlier in the same period of lactation, and throughout the previous period of lactation were available for comparison. The analyses of the last two samples before the injury are given, as they are typical of the milk normally obtained from the cow. The two samples consisted of three-day composites, one taken at about five weeks and the other at about two and one-half weeks prior to the injury. The sample taken after the injury consisted of a composite made from the evening milking on the day of the injury, and the morning milking on the day following. Since the injury became so severe that recovery was not expected, the cow was killed before further samples were taken.

The analytical data are as follows:

	TOTAL SOLIDS	ASH	FAT (ROBBE-GOTTLIEB)	TOTAL PROTEIN	LACTOSE (OPTICAL)	SPECIFIC GRAVITY
	per cent	*per cent*	*per cent*	*per cent*	*per cent*	
Five weeks before injury.....	11.92	0.77	3.96	3.56	3.77	1.0286
Two and one-half weeks before injury.....	11.55	0.64	4.00	3.13	3.72	1.0289
After injury.....	8.86	0.67	2.44	3.15	2.50	1.0244

The table shows that after injury there was a very decided drop in the percentage of total solids, fat and lactose, and in the specific gravity. There was practically no change in the percentage of ash or total protein. The differences in composition are ascribed to the effects of the injury.

The change in the percentage content of lactose is in agreement with

unpublished data obtained in this laboratory which indicate that the lactose of milk is especially sensitive to physiological disturbances.

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ERRATA

In the May issue of the Journal of Dairy Science, in the article by Messrs. R. F. Hunwicke and H. Jephcott, "The Destruction of Bacteria in the Roller Process of Milk Drying," the quoted paragraph at the top of page 208 should be inserted just after the word "summary," line 32, page 211. The paragraph in question is part of the quotation from Delepine's report.

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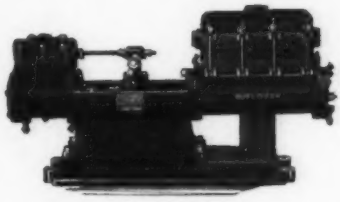
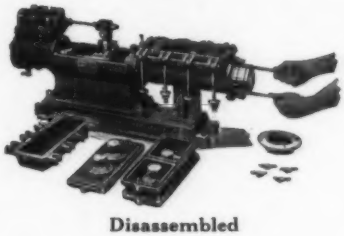
BUFFLOVAK

Sanitary Milk Pumps



Assembled



Disassembled

A pump that overcomes the difficulties peculiar to pumping milk product

THE BUFFLOVAK Sanitary Milk Pump overcomes the difficulties peculiar to pumping milk products. All parts in the liquor end of the pump including the cylinder, piston and valve mechanism, are made entirely of bronze, so that the most exacting sanitary requirements of the dairy industry are completely fulfilled.

The utmost accessibility is afforded by its simplicity of construction. By loosening eight nuts, the entire valve mechanism may be completely disassembled for cleaning.

The piston may be withdrawn after removing four wing nuts which hold the cylinder head in place.

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It is a principle of life, that it is not what a man knows but what a man does that counts.

Thousands of creamerymen, cheesemakers and dairymen not only know but also put to practical use the efficient and economical results of the distinctively safe, sweet and wholesome sanitary cleanliness which always follows the use of

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Cleaner and Cleanser

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Indian in circle

in every package.

Ask your supply man.

The J. B. Ford Company, Sole Mnfrs. Wyandotte, Mich.

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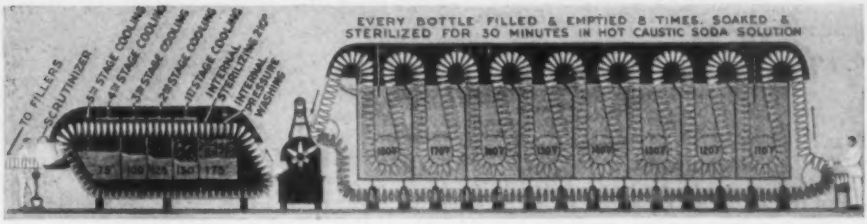
TO FILLERS
SCRUTINIZER
4TH STAGE COOLING
3RD STAGE COOLING
2ND STAGE COOLING
1ST STAGE COOLING
INTERNAL STERILIZING 210°
INTERNAL PRESSURE WASHING
EVERY BOTTLE FILLED & EMPTIED 8 TIMES. SOAKED & STERILIZED FOR 30 MINUTES IN HOT CAUSTIC SODA SOLUTION

Economy in Bottle Handling

THIS Giant Barry-Wehmiller unit delivers 180 clean, bacteriologically sterile bottles a minute. Every bottle is soaked for 30 minutes in caustic soda solution, washed by hot water at high pressure, sterilized at 210°, and cooled *without reinfection.* The B-W Soaker-Washer-Sterilizer is designed for economy as well as efficiency. Automatic transference of bottles, combining these processes in one continuous operation makes possible great economy in handling charges. Graduated temperatures prevent breakage of bottles; machinery is carefully designed to avoid wear and tear—repair bills are almost nil.

Exclusive Features

a. Complete mechanical separation of the soaking process, involving the use of caustic soda, from the washing, sterilizing and cooling processes.

b. Construction of soaker pockets, entirely free from lodging places for dirt, to allow easy access for cleaning.

c. Continuous motion in the soaker avoiding wear and tear on the heavier machinery.

d. Complete drainage of bottles as they emerge from soaker.

e. Automatic transference of bottles from one machine to the other.

f. Washing by hot water at high pressure from spindles entirely within the bottle and in close contact with the glass. (No unsanitary brushes.)

g. Complete separation of the carrying chain from interior of the washer and sterilizer, saving wear and tear on the chain and preventing reinfection of the bottles.

h. Step by step motion on the washer to insure thorough cleaning.

i. Cooling by application of water to the exterior only of the bottle.

Six of these B-W units are used in the largest plants of the Sheffield Farms Company, New York City. Adopted by one of the largest European Dairies.

Barry-Wehmiller approved "In the bottle" pasteurizers, used in combination with the Soaker-Washer-Sterilizer forms a most practical bottling system. At the Deerfoot Farms Dairy, Southborough, Mass., and the New Haven Dairy Company, New Haven, Conn., and A. Stapleton and Sons, Brooklands Farm, London, England, this system has proven very successful.

Many types and capacities, "Midget" to "Giant" size. Information gladly given.

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"You can feed a cow until she bursts, but she will not produce milk unless she has the inheritance for doing it."

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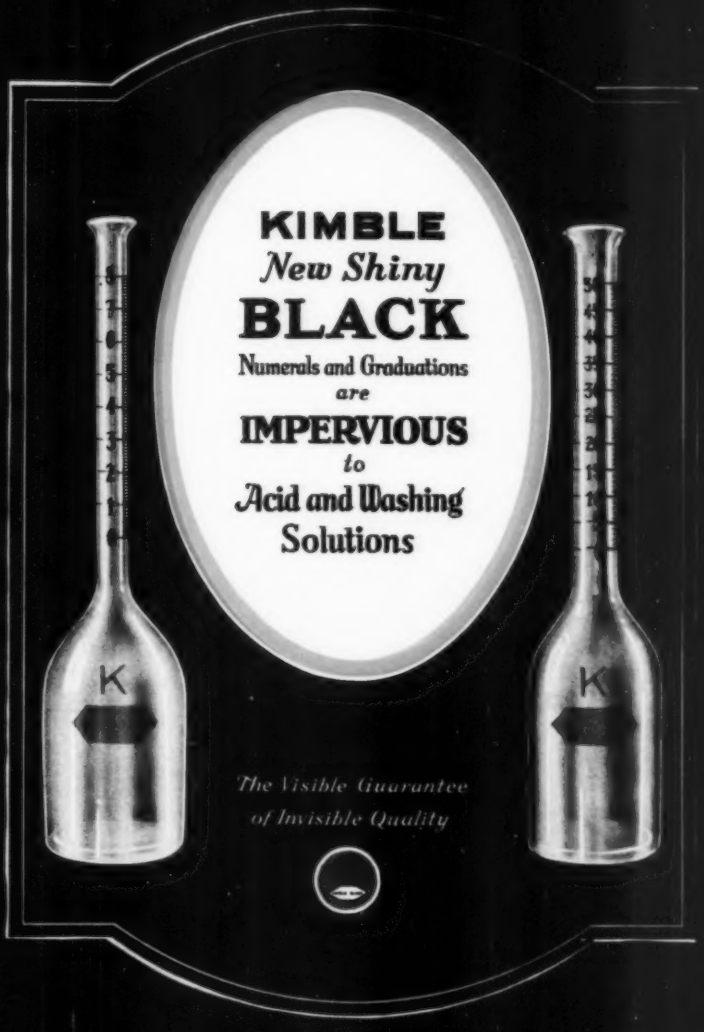
KIMBLE
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are
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to
Acid and Washing
Solutions
K
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of Invisible Quality

IT has always been impossible to obtain Test Bottles, on which the colored numerals and graduations would remain after many washings. This constant source of dissatisfaction has been absolutely eliminated by the New, Shiny Black, Impervious Kimble Filling.

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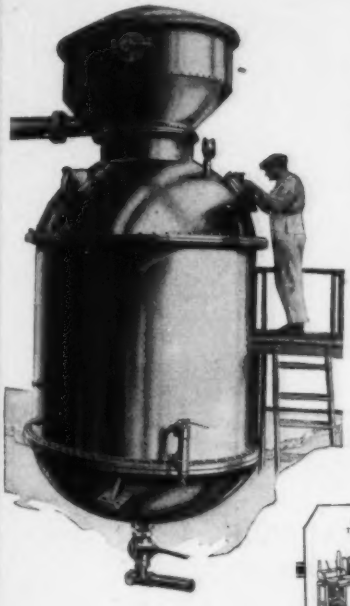

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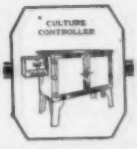
Scientific
Dairy Equipment



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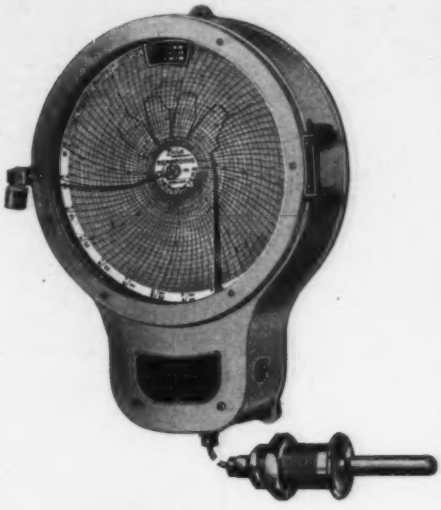

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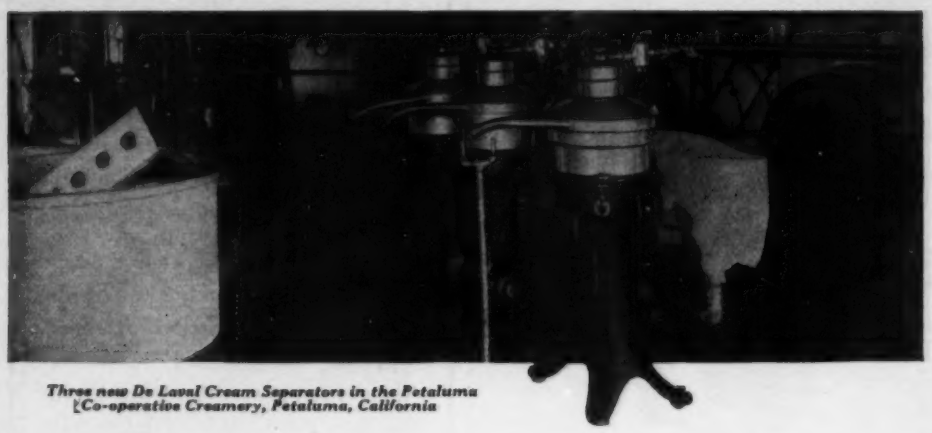

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